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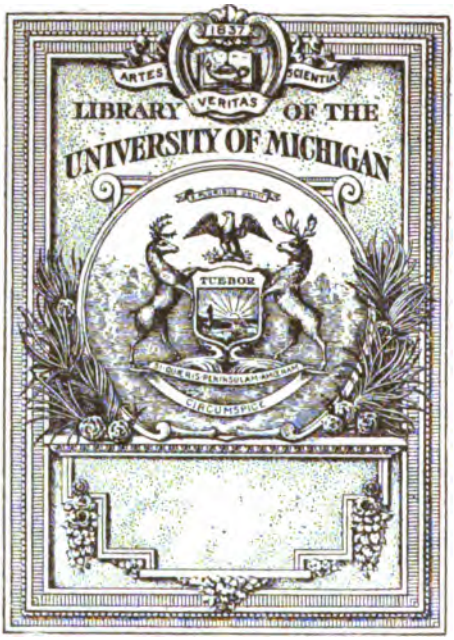
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ANIMAL AND VEGETABLE FATS AND OILS.

A PRACTICAL TREATISE

ON

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ANIMAL AND VEGETABLE FATS AND OILS:

COMPRISING BOTH FIXED AND VOLATILE OILS,

THEIR PHYSICAL AND CHEMICAL PROPERTIES AND USES, THE MANNER
OF EXTRACTING AND REFINING THEM, AND PRACTICAL
RULES FOR TESTING THEM;

AS WELL AS THE

MANUFACTURE OF ARTIFICIAL BUTTER AND LUBRICANTS, ETC.,

WITH LISTS OF AMERICAN PATENTS RELATING TO THE EXTRACTION, RENDERING,
REFINING, DECOMPOSING, AND BLEACHING OF FATS AND OILS.

BY

WILLIAM T. BRANNT,

EDITOR OF THE "TECHNO-CHEMICAL RECEIPT BOOK," "PETROLEUM," ETC.

SECOND EDITION, REVISED, AND IN GREAT PART RE-WRITTEN

ILLUSTRATED BY THREE HUNDRED AND TWO ENGRAVINGS.

IN TWO VOLUMES.

VOL. I.

PHILADELPHIA:
HENRY CAREY BAIRD & CO.,
INDUSTRIAL PUBLISHERS, BOOKSELLERS AND IMPORTERS,
810 WALNUT STREET.
LONDON:
SAMPSON LOW, MARSTON & CO., LIMITED,
ST. DUNSTAN'S HOUSE, FETTER LANE, FLEET STREET, E. C.
1896.

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HENRY CAREY BAIRD & CO.,
1896.

Printed at the
WICKERSHAM PRINTING HOUSE,
53 and 55 North Queen Street,
Lancaster, Pa., U. S. A.

PREFACE

TO THE SECOND EDITION.

THE rapid sale of the first edition of "A Practical Treatise on Animal and Vegetable Fats and Oils," and the continued demand for it, testify to its having filled a useful place in English technical literature.

It is quite unnecessary here to enlarge upon the vast importance and the commercial value of these materials, since they are indispensable requisites both in domestic economy and in the arts—equally important for food and as materials in the manufacture of soap, perfumery, lubricants, paints, varnishes, etc., and as sources of light. Since the classic researches of Chevreul and the more recent ones of Heintz, little that is new has been added to the chemistry of the fixed oils and fats, but the number of these fats and oils available for technical purposes has been largely augmented by the discovery and utilization of many new varieties. In order adequately to represent this advancement and development, it was felt that the second edition, which is now submitted to the public, required to be a more extended work.

In carrying out this project the first edition has been thoroughly revised and largely rewritten, and much time and care have been devoted to the gathering of information from all available sources. During the last few years several valuable works relating to the chemistry and technology of fats and oils have been published abroad, and these, as well as the voluminous literature scattered throughout the pages of numerous scientific and technical periodicals, have been freely consulted, with the object of bringing the work, as far as possible, up to date. Like the first edition, the book is divided into three parts.

Part I. treats of Fixed Fats and Oils. It is chiefly based upon the German work, *Die Technologie der Fette und Oele des Pflanzen-und-Thierreichs*, by Dr. Carl Schaedler, a second edition of which, edited by Paul Lohmann, has appeared since the death of Dr. Schaedler. While a considerable portion of this work has been incorporated into the present treatise, this information has, whenever required, been supplemented by fuller descriptions, especially of cotton seed and other American oils, and the processes of their extraction.

Part II. contains Volatile or Essential Oils. This portion of the work has been rearranged and almost entirely rewritten. Instead of being placed in alphabetical order, the oils have been classified according to their botanical derivations, such arrangement being, for reasons given later on, considered the most suitable. Thanks to the labors of Wallach and others, vast strides have in recent years been made in the elucidation of the chemistry of volatile oils, and these investigations, as well as all other available sources of information, have been consulted and made use of in order to render this portion of the work as complete as possible.

The Appendix—the third part of the book—is devoted to Lubricants. This portion has been considerably enlarged by the addition of practical receipts for axle-greases and lubricants of all kinds, and it is hoped that it will prove of value to those interested in the subject.

In brief, the object aimed at in the preparation of this edition has been to make it useful to all persons in any way interested in fats and oils, and especially so to analysts, pharmaceutists, chemists, manufacturers and technical students.

As is the general custom of the publishers, they have caused the work to be supplied with a copious table of contents, as well as a very full analytical index, which will render reference to any subject in both volumes prompt and easy.

WILLIAM T. BRANNT.

Philadelphia, September 10, 1896.

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ANIMAL AND VEGETABLE FATS AND OILS.

PART I.

FIXED FATS AND OILS.

CHAPTER I.

HISTORICAL NOTICE.

BUT little is known regarding the use of animal and vegetable fats and oils in the earliest ages of the world. However, the process of extracting fat oils from plants, and their employment for a variety of purposes, but principally as a means of illumination, was understood at an early period. In the writings of Moses oil is frequently mentioned, and it appears probable that the candlesticks so frequently referred to in Holy Writ served as a support for lamps and not candles. In Genesis Moses speaks of a *burning lamp*, and in the two following books it is clearly stated that olive oil was the material used as the source of light. The introduction of oils into Europe dates also from a very remote period. During the Trojan war the Greeks appear to have been ignorant of the mode of applying oil as a source of light, for Homer mentions wood torches as a means of illumination at that time, while according to Herodotus* the Greeks were the first European people acquainted with oils. They derived their knowledge of oil, and the means of procuring it, from the Cecrops, who brought olive oil from

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* Born 484 B. C., died 408 B. C.

Sais, a province of lower Egypt. Statements by Dioscorides* and Pliny† clearly show that, besides olive oil, the Greeks and Romans of the first century were acquainted with several other fat oils, such as castor oil, almond oil, nut oil, etc.

For obtaining the oil two methods were at that time in general use, viz.: expression, and boiling with water, the oil, in the latter process, separating on the surface.

It may be left undecided, whether the action of oil in quieting the sea, which in modern times has been repeatedly utilized with favorable results, was known to the Arabs and the navigators of the North, but it is an established fact that in Herodotus' times it was made use of by the Greeks in their venturesome voyages in open boats across the Mediterranean.

Unequivocal references to butter were first made by Herodotus and Hippocrates,‡ both stating that the Scythians by vigorously agitating the milk of their horses and separating the mass collecting on the surface, obtained a product which Hippocrates calls *βούτςρον*—butter. Dioscorides was cognizant of the fact that the best butter is obtained from the fattest milk, for instance goat milk or sheep milk, and that it may be used as a substitute for oil in dressing vegetables; further that, like other fats, butter is combustible, and he speaks of the soot obtained in burning it in a lamp as a medicine. The process of saponification has thrown most light upon the chemical nature of fats. This process was known in olden times, but that it was understood at an early era is not proven by the occurrence of the word "soap" in several places in the translation of the Old Testament§, for it is positively asserted by distinguished linguists that the actual meaning of the word thus rendered is "alkaline lye of a plant." Even Dioscorides appears not to have been acquainted with soap, though he mentions a preparation made of vine-ash and oil or fat as a remedy for external use in many ailments.

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* A Greek physician about 50 A. D.

† Born 23 A. D., died 79 A. D.

‡ A Greek physician, B. C. 460–377.

§ Jeremiah, ii, 22; Malachi, iii, 2.

The earliest mention of the term "soap," as applied to the substance known to us, occurs in Book XVIII. of Pliny's "Historia Naturalis," but he refers to it rather as an emollient and discussive remedy for external use, and calls it *sevum caprinum cum calce.*

Soap prepared from beech-ash and goat-fat was used as a means for beautifying the hair.

The celebrated physician Galen* says, German soap is the best, because it is fattest; and next to it is Gallic soap, because it has an emollient effect, and is used for removing dirt from the body and from clothes. The invention of soap is without doubt either of German or Gallic origin. The reason of German soap being distinguished by Galen as fatter (softer) than the Gallic product, may very likely be found in the fact that the former was prepared with alkali from the ash of land plants (potash), and the latter with ash of marine plants (soda).

The ancient Egyptians were acquainted with plasters containing white lead, such a plaster invented by King Attalus III.† being very celebrated. Dioscorides states that oxide of lead when boiled with oil acquires the color of leather and yields a plaster.

Pliny was acquainted with the solubility of resins in oil. He speaks of the preparation of remedies by dissolving resin in oil, and says positively: "*Resina omnis dissolvitur in oleo.*" The alchemist Basilius Valentinus‡ was the first to apply the term "balsam of sulphur" to a solution of sulphur in olive oil, linseed oil, etc.

The ideas regarding the chemical constitution of fats, oils and soaps were very crude, and as late as the 17th and 18th centuries the opinion prevailed that in the formation of soap the fat simply combines with the alkali. Otto Trachenius,§ however, said that oil or fat contains a "verborgene Säure"

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* Born 131 A. D., died about 200 A. D.

† Died 133 B. C.

‡ Towards the end of the 15th century.

§ Born at Herford, Westphalia; died 1696, at Venice.

(hidden acid), and he was, therefore, cognizant of the fact which, nearly two centuries later, rendered Chevreul's name immortal.

Some chemists observed that fat, when for some time in contact with metal, attacks the latter, and from this inferred a content of acid. Joseph Geoffroy,* in 1741, was the first to recognize the fact that fat separated from soap by means of acid possesses different properties from the fat used in the preparation of soap, it dissolving, for instance, with greater ease in alcohol, and Berthollet† showed that fat combines not only with alkalies, but also with earths and metallic substances by mixing a solution of ordinary soap with solutions of earthy and metallic salts. He prepared several such combinations, and in 1780 laid them before the Paris Academy.

Even Scheele's‡ discovery in 1783, that by the action of lead oxide upon olive oil a peculiar sweet substance—*principium dulce oleorum*—glycerin—is separated, which, when treated with nitric acid, yields oxalic acid, remained without influence upon the theory of the formation of soap. In the succeeding year Scheele established the presence of the same substance in lard and butter. However, he failed to recognize the importance of this body in relation to the formation of soap and up to his death was of the opinion that oils are composed of carbonic acid, water and phlogiston, *i. e.*, the base of inflammability and the products of combustion.

Antoine Laurent Lavoisier,§ the discoverer of oxygen and founder of the antiphlogistic theory, hence of modern chemistry, by burning olive oil and calculating the results found that the oil contains 78.9 per cent. carbon and 21.1 per cent. hydrogen, and therefore considered it a hydrocarbon.

In the commencement of the present century the various kinds of fat were not considered different combinations of a few specific constituents, but more simple organic combinations differing one from another like, for instance, the various kinds of sugar, the derivation and consistency serving as bases of distinction. They were divided into fat oils—drying and non-drying—vegetable butter, wax, train oil, lard, etc. Adipocere* was first discovered by Foucroy in the Cimetière des Innocents when it was removed in 1787; adipocere was classed with spermaceti.

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* Born August 8, 1686; died March 9, 1752.

† French chemist, born 1748; died 1822.

‡ Swedish chemist, born Dec. 2, 1742; died May 21, 1786.

§ French chemist, born August 16, 1743, died May 8, 1794.

In 1813, thirty years after the discovery of glycerin, Michel Eugene Chevreul†, by his memorable investigations, threw light upon the constitution of fats and the formation of soap, and led the way to the distinction of fatty acids, the issue of these discoveries being the fatty acid industry, commenced in 1828, and at present developed to enormous proportions.

Further historical data belong to more modern times and are referred to in the text.

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* A soft unctuous or waxy substance, of a light brown color, into which the fat and muscular fibre of dead animal bodies are converted by long immersion in water or spirit, or by burial in moist places under peculiar circumstances.

† Born at Angers, August 31, 1786; died at Paris, August 9, 1889, at the age of 103.

CHAPTER II.

OCCURRENCE OF FATS AND OILS—VEGETABLE FATS—ANIMAL FATS—DETERMINATION OF THE CONTENT OF OIL AND FAT, AND DETERMINATION OF THE VALUE OF OIL SEEDS—EXTRACTIVE CONTENT OF FAT.

THE term *fats* is applied to a series of organic substances, colorless or of all possible colors, which at the ordinary temperature are either solid, soft, or fluid. In a pure state they are nearly odorless and tasteless, but as ordinarily met with in commerce, they possess a characteristic odor not always agreeable. By the application of heat they are only partially volatilized without suffering decomposition, if special precautionary measures are used. Upon paper they produce a permanent grease spot. Such, briefly, are the principal characteristics of a group of bodies widely distributed throughout nature. When solid they are briefly called *fats*, and when fluid *oils;* between them are the butters, which are soft varieties of fats possessing the physical texture of cow's butter. *Waxes* have at the ordinary temperature a firm texture, but when heated melt to liquids, which closely resemble, in their general physical characters, ordinary liquid oils and melted fats.

Certain other bodies, partially prepared artificially and partially occurring in nature, possess properties similar to those of natural fats. To the former belong the hydrocarbons formed by the destructive distillation of resin, lignite, coal, wood and bones, and to the latter the hydrocarbons furnished by nature such as petroleum, ozocerite, etc. All of them, when properly purified, possess properties similar to those of the fats, and may, for special purposes, serve as substitutes for them. However, they differ materially from them as regards their composition and chemical behavior.

Another group of bodies commonly called *volatile* or *essential* oils have nothing in common with the actual fats except a certain lubricity and the property of producing upon paper a grease spot, which, however, is only temporary.

In this portion of the work only the actual fats and fat or fixed oils will be discussed, the volatile or essential oils being treated of in the second part.

The fats and fat oils are composed of carbon, hydrogen and oxygen. According to the idea formerly held they are considered salt-like combinations, since they can be resolved into glycerin and acids belonging to the so-called fatty acids.

The fats occurring in nature are always mixtures of various glycerides of olein, palmitin, stearin, etc., but besides them contain occasionally sulphur combinations as, for instance, the crude oils of the cruciferous plants, or phosphor combinations in the form of lecithine or protagon, as in pea oil. (For details see Chapter VI.)

I. VEGETABLE FATS.

These fats are widely distributed throughout the vegetable kingdom; they occur as constituents of the cell-content, but may also be distributed in the protoplasm as well as the cell-juice. In cells rich in protoplasm of oleiferous seeds they are imbedded in the protoplasm in the form of very small globules forming, like in milk, an emulsion. As a rule the juice-space of each cell contains a single large orbicular oil-body—drop of fat—which frequently occupies a large portion of the cell-space. Sometimes the fat also forms a ball, as in the cacao seed. There is no seed which does not contain at least a few per cent. of fat, but as a rule amylaceous seeds contain less fat than seeds free from starch, and, under all conditions, the axis of the embryo (the radicule, hypocotyle and plumule) is the portion of the seed relatively richest in fat. Generally speaking the limpid oils, *i. e.* those richer in oleic acid, seem to be stored in the axis of the embryo, while the cotyledons and the endosperm* are richer in more solid fats. Crystals of fatty acids occur in the endosperm of the palms—*Elais guineënsis, Cocos nucifera, Astrocaryum vulgare, Virola sebifera,* etc. These fruits and oil-seeds may also contain: *Protein* substances; *chlorophyl* (pericarp of the olive; pistacia nuts); *granular coloring matter* (seed tissue of *Virola sebifera); fluid coloring matter* (palm butter, fruit of *Astrocaryum vulgare); resin* (cotton seed); more rarely, *starch* (acorns, nutmegs), and very seldom in the decaying cell-wall, as, for instance, the tissue of the beet —*Beta vulgaris.* Seeds rich in fat sometimes contain also granular (crystalline) formations, *aleuron bodies* or *gluten* (in the cacao seed, castor bean, Para nut) which, according to Sachs, are a mixture of fat with albuminous bodies. The gluten occurs in a roundish or polyhedral form, and is formed only when the seed is nearly ripe; when the latter germinates the gluten is redissolved.

In some cases the globular drops of fat are enveloped in a peculiar, delicate membrane, as in the olive.

No portion of phenogamic, as well as cryptogamic, plants is entirely wanting in fat, the latter differing from that of the seeds only by its more wax-like character. Fats in large quantities appear as reserve-nutriment in fruits and seeds, more rarely in underground parts of plants, as in the rhizome of *Cyperus esculentus.*

In the vegetable kingdom *wax* occurs especially as a coating upon stalks, leaves, fruits, and other portions of plants; in larger quantities it is found upon the trunks of some palms, such as *Copernica, Ceroxylon,* etc.

The wax is formed in the cuticle of the epidermis of the portion above ground, and in many plants exudes as a secretion in the form of a very thin whitish film, which can readily be wiped off, as, for instance, upon the green portions of cabbage, poppies, peas, as well as upon plums, grapes, and many other hairless parts of plants. The seeds of *Stillingia sebifera*, the Chinese tallow tree, are coated with a hard layer of tallow, which no doubt is formed in the same manner as wax.

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* An oleiferous perisperm does not appear to exist.

Fat in various quantities is stored in the *roots* of gentian—*Gentiana*, rhubarb—*Rheum*, rest-harrow—*Ononis;* in the *rhizomes* of *Cyperus esculentus*, hellebore—*Veratrum*, ferns—*Filices;* in the *bulbs* of the onion—*Allium cepa*, squill—*Scilla maritima;* in the *tubers* of meadow-saffron (colchicum)—*Colchicum;* in the *stem* of the mistletoe—*Viscum album;* in the barks of the willow—*Silex*, horse-chestnut—*Aesculus;* in the *leaves* of the bitter polygala—*Polygala*, clover—*Trifolium carnatum*, *Holeus lanatus;* in the *flowers* of the chamomile—*Chamomilla;* in the *endoscarps* of the olive—*Olea*, laurel—*Laurus*, oil-palm—*Elais;* in the *seeds* of the cruciferous plants, *Papaveraceae*, *Amygdaleae*, etc., in the *spores* of Lycopodium; in *fungi*, such as ergot, yeast, etc.

The following plants arranged according to de Candolle's improved system, yield chiefly fats and oils which are technically utilized.

The fat of the plants marked with an asterisk (*) is obtained in the countries of their growth, and is directly brought into commerce, generally from the tropics.

The seeds and fruits of the other plants have become articles of commerce, and the oil from them is limited neither by location nor time:

1. CÆSALPINIACEÆ.
    - *Arachis hypogæa* L. }
    - " *africana* Lour. } Ground-nut or pea-nut oil.
    - " *americana* Ten. }
    - *Moringa oleifera* L. } Africa, South America—ben
    - " *pterygosperma* Gaert. } oil.
2. AMYGDALEÆ.
    - *Amygdalus communis* L.—almond oil.
    - " *Persica vulgaris* L.—peach oil.
    - *Prunus domestica* L.—plum-kernel oil.

3. Pomaceæ.
  Cydonia vulgaris L.—quince-seed oil.
  Pyrus Malus L.—apple-seed oil.
4. Cassuvieæ.
  Semecarpus orientale L.—East Indies, cashew-apple oil—*Huile de noix acajou.*
5. Burseraceæ-Amyrideæ.
  **Irwingia Barteri* Hook.—South Africa—dika fat.
6. Celastrineæ.
  Evonymus europæus L.—spindle-tree oil.
7. Euphorbiaceæ.
  **Stillingia sebifera* Willd.—China—Chinese tallow.
  **Aleurites moluccana* Willd.—Java, Moluccas—candle-nut oil.
  Croton Tiglium L.—East Indies—croton oil.
  Ricinus communis L.
  " *viridus* Willd. } East and West Indies. } Castor oil.
  " *inermis* Jaqu.
  Euphorbia Lathyris L.—France—purging oil.
  Jatropha curcas L.—South America—purgir-nut oil.
8. Sapindaceæ.
  Sapindus Saponaria L.—West Indies. } Soap-tree oil.
  " *emarginatus* Vahl.—East Indies.
  Schleichera trijuga Willd.—Sunda Islands—macassar oil.
  Pekea butyrosa Aubl.—Guiana—pekea tallow.
9. Ampelideæ (Meliaceæ, Sarmenteæ).
  Carapa guianensis Aubl.—West Indies. } Carapa oil.
  " *Touloucana* P.—South America.
  Vitis vinifera L.—grape-seed oil.
10. Lineæ.
  Linum usitatissimum L.—linseed oil.
11. Dipterocarpeæ.
  **Vateria indica* L.—East Indies—piney tallow.
  **Hopea macrophylla* de Vriese. } Sunda Islands. } Borneo tallow.
  * " *lanceolata* de Vriese.
  **Lophira alata* Schw.—Africa—Niam fat.
12. Malvaceæ—(Bombaceæ).
  Gossypium herbaceum L.
  " *arboreum* L.
  " *ramecosum* L. } West Indies, East Indies, Africa. } Cotton-seed oil.
  Bombax heptaphyllum L.
  " *malabaricum* L.

13. STERCULIACEÆ.
Sterculia fœtida—India—stinking-bean oil.

14. BUETTNERIACEÆ.
Theobroma Cacao L. } Mexico, }
" *bicolor* Humb. } tropical } Cacao butter.
" *Guianense* Willd. } America, }

15. CAMELLIACEÆ.
Camellia japonica L.—Japan. }
" *oleifera* L.—China. } Tea-seed oil.
" *drupifera* L.—Cochin China. }

16. MYRTACEÆ.
Barringtonia speciosa L.—India—Barringtonia oil.
Bertholettia excelsa Humb.—South America—Brazil-nut oil, or Para-nut oil.

17. COMBRETACEÆ.
Terminalia Catappa L.—India, Java—jungle-almond oil.

18. CLUSIACEÆ OR GARCINIEÆ.
**Pendadesma butyracea* Don.—Sierra Leone.
**Garcinia purpurea* Roxb.—India—Kokum fat, or Goa butter.

19. MYRISTICEÆ.
**Myristica moschata* L. Moluccas—expressed oil of nutmegs.
**Myristica Otoba* Humb, et Bonpl.—New Granada—Otoba butter.
**Myristica officinalis* Mart.—Brazil—Becuiba tallow.
**Virola sebifera* Aubl.—West Indies—Virola tallow.

20. CUCURBITACEÆ.
Citrullus species. } East } Water-melon oil, cucumber-seed,
Cucumis species. } Africa. } oil, etc.

21. CRUCIFERÆ.
Sinapis nigra L.—*Brassica nigra* K. }
" *alba* L. }
" *juncea* L. } Mustard-seed oil.
" *campestris* L. }
Brassica Napus L.—*oleifera annua.* }
" " " *biennis.* } Rape-oil.
" *præcox* Dec. }
" *campestris* D. C.—colza oil.
" *Rapa* L.—turnip-seed oil.
Raphanus sativus L.—radish-seed oil.

Hesperis matronalis L.—hesperis oil; *Huile de julienne.*
Lepidium sativum L.—cress-seed oil.
Camelina sativa L.—German sesamé or camelina oil.

22. PAPAVERACEÆ.

Papaver somniferum nigr. L.	Poppy-seed oil.
" " *alb.* L.	

" *Glaucium* L.—horned poppy-seed oil.

23. RESEDACEÆ.

Reseda Luteola L.—weld-seed oil.

24. BIGNONIACEÆ OR SESAMEÆ.

Sesamum indicum L., India.	Sesamé or gingelly oil.
" *orientale* L., Levant.	
Bignonia tomentosa Thunb., Japan.	

25. OLEINEÆ.

Olea europæa L.—olive oil.

26. SOLANEÆ.

Nicotiana tabacum L.—tobacco oil.
Atropa belladonna L.—belladonna-seed oil.

27. SAPOTEÆ.

Bassia butyracea Roxb.	West Africa.	Bassia fat, Mahwa butter, Illipé butter, Galam butter, Shea butter, etc.
" *latifolia* "		
" *longifolia* "		
" *Parkii* D. C.		

28. COMPOSITÆ.

Helianthus annuus L.—sunflower oil.

Madia sativa Mol., Chili.	Madia oil.
Guizota oleifera D. C., East Africa.	
Polymenia abyssinica " "	

Onopordon Acanthium L.—thistle-seed oil.

29. LAURINÆ.

Laurus nobilis L.—South Europe—laurel oil.

Laurus glauca Thunb., Japan.	Laurel butter.
Tetranthera laurifolia Jaq.	

**Lepidadenia Wigthiana* Nees, Java—tangkallak-fat or Java oil.

30. URTICEÆ OR CANNABINEÆ.

Cannabis sativa L.—hemp-seed oil.

31. JUGLANDEÆ.

Juglans regia L.—Persia, Himalaya—walnut oil.
Carya amara C. *alba* Mich., North America—hickory-nut oil.

32. CUPULIFERÆ.
Fagus sylvatica L.—beech-nut oil.
Corylus avellana L.—hazel-nut oil.

33. CONIFERÆ.
Pinus Abies L.—pitch-tree oil.
Pinus sylvestris L.—pine-tree oil.
Gingo beloba L.—Japan—gingo oil.
* *Cocos nucifera* L. Brazil.
* " *butyracea* L. Cocoa-nut oil.
* *Attalea Cohune* Mart., Honduras.
* *Elais guineënsis* L.
* " *melanococca* Gært.
* *Alfonsia oleifera* Humb. Brazil.
* *Astrocaryum vulgare* Mart.
* *Guilielma speciosa* Mart., New Granada. Palm oil.
* *Œnocarpus baccata* Mart., Guiana.
* " *Batava* Mart., Orinoco.
* *Acrocomia sclerocarpa* Mart., Jamaica.

35. GRAMINEÆ.
Zea mais L.—maize oil.

36. CYPERACEÆ.
Cyperus esculentus L.—cyperus-grass oil.

II. ANIMAL FATS.

The fats of the animal body are present in all tissues and organs, and in all fluids except normal urine.

The most fat occurs in the higher classes of animals, while in the lower organisms it is entirely wanting.

Enclosed in special cells the fat occurs in the fatty tissue, and collects in larger quantities in separate parts of the body; certain fluids are also distinguished by their richness in fat, for instance, milk.

The fats penetrate the muscular flesh and are met with in large quantities especially beneath the skin, in the eye-sockets, around the heart, in the tissues, in the abdominal cavity, in the intestines, in and around the kidneys, and in the cavities of the bones.

At the normal heat of the animal body—of a grown healthy human being, 99.5°F., of mammals, 96° to 101.3°F., of birds, 103.1° to 109.4°F.—the fat is always fluid and oil-like.

The distribution of fat in the various animal tissues and fluids is shown in the appended table, in which the figures indicate the average value of fat.

Bone marrow	96.00	per cent.	Liver	2.40	per cent.
Fatty tissue	82.70	"	Bones	1.50	"
Spinal marrow	23.60	"	Gall	1.40	"
Brain (white substance)	20.00	"	Blood	0.40	"
Hen egg	11.50	"	Saliva	0.02	"
Milk	4.50	"	Sweat	0.001	"
Muscles	3.30	"			

Since all animal fats can be technically utilized, it has been considered unnecessary to group the various fat-yielding animals together according to families.

III. DETERMINATION OF THE CONTENT OF OIL AND THE VALUE OF OIL-SEEDS.

As previously mentioned, in plants the largest content of fat is found in the seeds and fruits, and this content depends upon the manner of cultivation, condition of the soil, manure, weather, degree of ripeness, etc. The content of fat in seeds and fruits is in an inverse ratio to that of sugar and starch: the higher the content of fat the smaller that of starch and sugar.

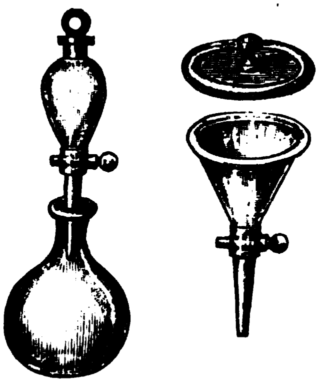
Before the introduction of new varieties of oil seeds, it is of great importance to know their exact content of fat, this being also necessary in selling and buying oil-seed, because the price of an article depends on the content of its principal constituent. The percentage of fat is rarely determined by expressing larger quantities of seed, but exclusively by extracting smaller quantities of average samples. The oldest method of determining the percentage of fat is by means of a separatory funnel—Fig. 1. Ether, petroleum-ether, canadol,* benzole (rarely carbon disulphide) serve as solvents.

* "Canadol" is the term applied by H. Vohl to that portion of the volatile hydrocarbons of Pennsylvania petroleum which boils at 60° C. (140° F.), and has a specific gravity of 0.650 to 0.700.

Comminute as finely as possible 200 to 300 parts by weight of the oleaginous seed or fruit to be examined, mix thoroughly, and put 10 to 20 parts by weight into the separatory funnel, previously provided with a tuft of cotton or a filter. Close the cock, pour the heated solvent upon the substance and allow it to stand half an hour. On opening the cock and removing the lid, the extract is discharged into the distilling flask. The operation is repeated until the fluid running off appears colorless and leaves no fat stain upon white paper. When rightly conducted, about 40 parts by weight of solvent are required for 10 parts by weight of substance.

After connecting the flask with a cooler, the solvent is distilled off. The residue is placed in a tared beaker-glass and heated in a water bath until the weight remains constant.

FIG. 1.



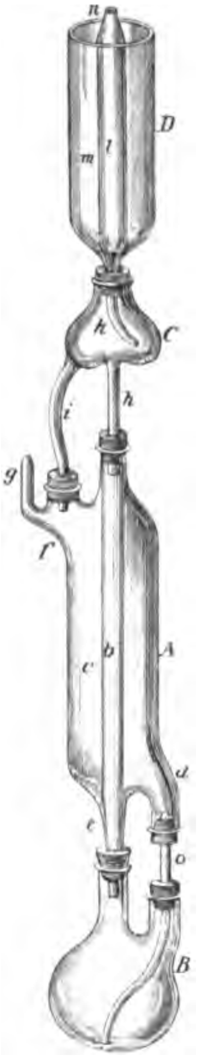
SEPARATORY FUNNEL.

The content of fat thus found is somewhat too high on account of resin and coloring matter having also been dissolved.

This method of extracting with the separatory funnel has been almost entirely abandoned. There are now a number of instruments by means of which the fat-holding solvent is immediately vaporized and conducted into a condenser, so that the same quantity of solvent may be re-used for extracting the fat.

The oldest and very excellent instrument is that of Vohl (erroneously called oleometer)—Fig. 2.

FIG. 2.



VOHL'S OLEOMETER.

The apparatus, entirely constructed of glass, consists of four principal parts, the extractor *A*, the boiling flask *B*, the head piece *C*, and the condenser *D*. The extractor consists of the inside tube *c c* with the narrow tube *b* blown in. The latter communicates by the tube *o* with the boiling flask *B*. On the side of *c c* is the tube *d*, in which *o* is inserted by means of a cork. *o* runs to the bottom of *B*, so that it is always closed by fluid. On the other, upper side of *c c*, is the tube *f*, in which is the tube *g* drawn out to a very narrow opening.

The head piece *C* connects by the tube *h* with the tube *b*, and by the tube *i* with *f*, respectively with the wide tube *c c* of the extractor. It further connects by the tube *k* with the tube of the condenser *D*; *m m* is open on top. At *n* the tube *l* is reduced to one-third of its clear diameter.

The apparatus is used as follows: The extractor *A* is stoppered at *d* with a loose plug of cotton, and the tube *c* introduced through a perforated cork. The seed, previously crushed and weighed, is then introduced into the tube *c c* through the tubulure *f*. The seed is uniformly distributed with a spatula and should not fill *c c* more than seven-eighths. The extractor is then connected by the tubes *c* and *o* with the flask *B*. Canadol is now poured through the tubulure *f* upon the substance until about three-quarters inch of fluid has collected in *B*. The head piece *C*, with the condenser *D*, is then placed in position and the tube *m m* filled with cold water or ice. The fluid in *B* is then brought to the boiling point, the vapors ascending through *o* to *b*, and condensing, return to *B* until the contents of *c c* have acquired the temperature of the boiling canadol. The vapors then ascend through *h* into the head piece *C*, where they are at first completely condensed; but later on, when *C* becomes strongly heated, the vapors pass through *k* into *l*, where they are completely condensed and then return through the tube *k* to *C*.

The condensed canadol vapors pass through *i* and the tube *f* into *A*, and finally return through the tube *c* to *B*. The tube *g* serves for the discharge and introduction of atmospheric air.

Considerable quantities of seed can be extracted in this manner by the use of comparatively little canadol.

When the fluid runs off clear and colorless at *c*, it may be assumed that the seed is entirely exhausted. After separating the canadol from the oil by distillation, the oil is weighed. The specific gravity of the canadol used should not be more than 0.66 to 0.68, and its boiling point not higher than 122° to 140° F.

With some experience the determination with this instrument can be conveniently made in one and a half to two hours.

With frequent and many determinations of oil, the distillation of the canadol extracts consumes time, requires great care, and besides it is necessary to procure distilling and evaporating apparatus, with the manipulation of which not every one is conversant. Vohl has therefore endeavored to volumetrically determine the content of oil.

The specific gravity of fat vegetable oils is considerably higher than that of the canadol used for extraction, and for this reason the specific gravity of the canadol extract must increase with the increase in the content of fat oil.

Vohl has tested mixtures of various oils, which also have different specific gravities, with canadol as to their specific gravity, and has compiled special tables* for linseed oil, hemp oil, poppy oil, walnut oil, almond oil and grape-seed oil.

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* Dingler's Polyt. Jour., CC, 413.

These tables are here omitted, because the above-mentioned number of oils is only a small one, and the specific gravities refer to the use of canadol of 0.68 specific gravity, which cannot always be had in commerce.

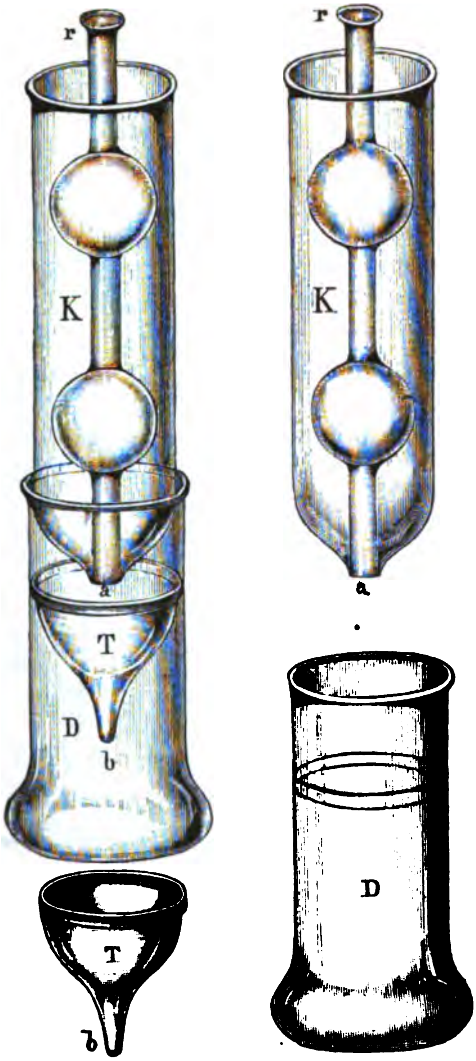
Edward Thorn's Extractor. This apparatus is based upon the same principle as Vohl's, and on account of its simplicity will very likely supersede the latter. It renders possible an exact and rapid execution of the quantitative analysis of seed, the fat being directly determined by means of the extractive process, or indirectly from the residue exhausted by an extractive agent.

The apparatus (Fig. 3), constructed entirely of glass, consists of the flask *D*, the funnel *T*, and the cooling cylinder *K*, with the condensing pipe *a r*.

When using the apparatus, the weight of the flask *D*, previously dried at 230° F., is first carefully ascertained. About 20 cubic centimeters of the required extractive agent (canadol, ether, benzole, carbon disulphide, etc.) are then introduced. A small weighed filter is placed in the funnel *T*, and after ascertaining the total weight, a weighed sample of the substance to be analyzed for fat is brought upon the filter. The funnel is then placed in the flask *D*, and the latter clamped into a stand, and the cooling cylinder *K* inserted, which is charged with water or, if necessary, with a freezing mixture. When working with very volatile liquids, the tube *r* is lengthened by inserting another narrower tube.

By now heating the fluid in the flask *D* in a water bath, the vapors condense in the bulbs of the condenser, and from there, as soon as the heat somewhat decreases, flows back upon the substance in the funnel. By repeated contact with, or removal of, the source of heat, this process is maintained until the extraction is completed, which may be ascertained by removing the funnel and allowing a drop to flow upon a watch-glass. When the process is finished, the extracting agent is driven as much as possible into the bulb tube, the upper orifice of which at *r* is then closed with the finger, when it may be removed

Fig. 3.



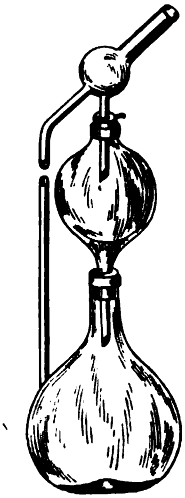
THORN'S EXTRACTION APPARATUS.

with most of the liquid. The quantity of extractive may be ascertained either from the increase of weight of the flask *D*, or from the decrease of weight of the funnel *T* with contents, dried in either case at 230° F.

Drechsel's and Soxhlet's apparatuses are also much used.

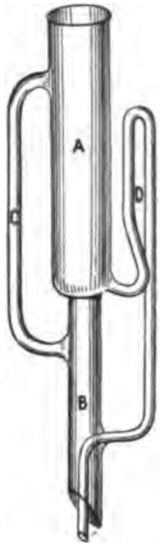
Drechsel's Apparatus. Fig. 4 with a Liebig condenser and Soxhlet's apparatus, Fig. 5, with an upright Hofmann condenser, or still better, with an Allihn's reflux condenser, Fig. 6.

FIG. 4.



DRECHSEL'S APPARATUS.

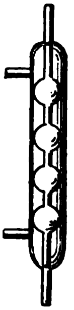
FIG. 5.



SOXHLET'S APPARATUS.
A, glass cylinder; *B*, tube joined to *A*; *C*, vaporizing tube; *D*, siphon.

In the first apparatus a plug of cotton freed from fat serves as filtering material, and in the latter, filter-paper shaped so as to form a cylindrical case. The latter is formed by wrapping a piece of filter paper twice around a cylindrical piece of wood of a somewhat smaller diameter than the inner width of the cylinder *A*, so that a portion of the paper, corresponding in length to the piece of wood, projects above the end of the latter. The portion thus projecting is turned down like closing a package and smoothed by vigorous pressure. Through such paper case the ether filters as clear as through an ordinary filter.

FIG. 6.



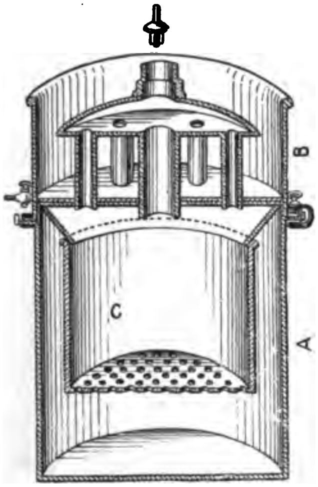
ALLIHN'S REFLUX-CONDENSER.

For the extraction in the laboratory of larger quantities (7 to 10 ozs.) of seed, *Thorn's copper extractor*, Fig. 7, is very suitable. It is constructed according to the same principle as Thorn's apparatus described on p. 18.

Wegelin–Hübner's apparatus, Fig. 8, is also very suitable for the purpose; it is arranged as follows:

The lower portion *B*, provided with thermometer *E*, serves as a paraffin bath and may be heated with gas or alcohol. In the bath *B* is suspended a vessel for the reception of the extractive agent, and in this vessel a smaller vessel with perforated bottom, or provided with a bottom of filter-cloth for the reception of the pulverized

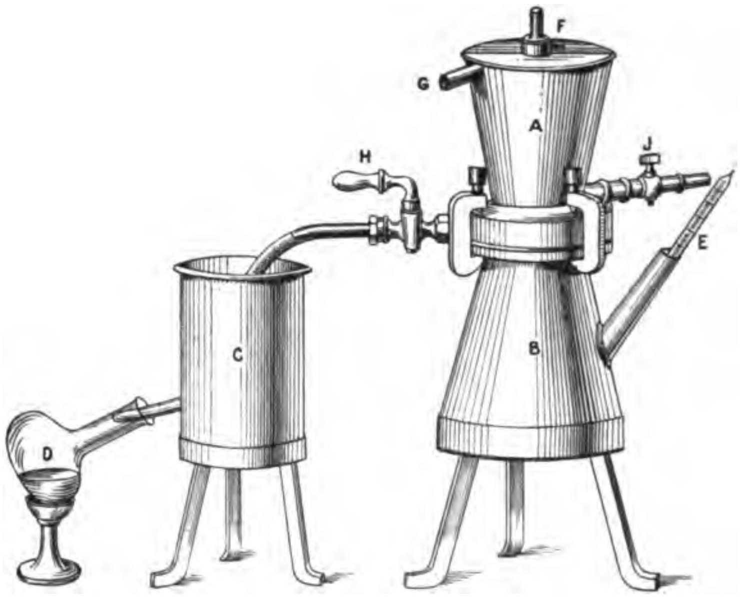
FIG. 7.



THORN'S COPPER EXTRACTOR.
A, distilling cylinder; *B*, condenser; *C*, extracting vessel.

seed to be analyzed. The condenser *A* is then placed in position and secured by three screws. The vessel is double-walled and so arranged that the interior of the double wall communicates with the interior of *B*. Into the middle of the hollow space at *I*, cold water is admitted which runs off at *G*. While the paraffin bath is being heated to the required temperature, the cock *G* remains closed. The extractive agent evaporates, ascends in the condenser, and when condensed flows back upon the substance. The fluid impregnated with oil passes through the filter-bottom of the seed-holder into the wider vessel suspended in *B*, where the extractive agent recommences its circuit, while the oil remains behind. *F* is a pressure regulator. The operation is finished in 1 to 1½ hours, when the water is discharged from the condenser *K*. The cock *H* is then opened

Fig. 8.



WEGELIN AND HÜBNER'S DISTILLING APPARATUS.

A and *C*, condensers; *B*, paraffin bath with extracting vessel; *D*, flask; *E*, thermometer; *F*, valve for regulating pressure; *G*, outlet for water; *I*, inlet for water.

and the fluid distilled through the condenser *C* into the receiver *D*. When sufficiently cooled off, the apparatus *A B* is taken apart and the oil weighed.

In the examination of seed as to its constituents, the following points have to be taken into consideration besides the content of fat (extraction with canadol):—

1. *Content of water*, which varies between 5 and 10 per cent.
2. Substances extractable with water, such as *sugar, gum and mucilage*, which amount to from 12 to 25 per cent.
3. *Resin* soluble in ether.
4. *Cellulose and other substances* insoluble in water and ether, which amount to about 7 to 15 per cent.
5. Content of *ash*, which is between 3 and 12 per cent.

Calculation.

Taking as a basis the average content of oil in seeds—which is given in the appended table—and the current price which has to be taken as a standard for this content of oil, the value of an oil-seed, may it be higher or lower than the supposed standard content, can be readily determined.

Suppose 100 lbs. of colza seed—*Brassica campestris*—cost $3.75, then seed containing only 36.5 per cent. oil will be worth less, viz., according to the following formula:

$$\frac{36.5 \times 3.75}{40.00} = 3.42$$

or 33 cents less.

Of course in this calculation only the content of oil is taken into consideration and not the feed-value of the seed-residue.

The appended table gives the extractive content of fat in oil seeds and fruits used in various countries or occurring in commerce, as well as of fats and oils partially introduced, or still to be introduced.

The animal fats are treated of in nearly the same order.

TABLE OF THE EXTRACTIVE CONTENT OF FAT IN VARIOUS SEEDS AND FRUITS.

Name of Oil, etc.	Botanical Name of Plant from which derived.	Family of Plants.	Native Country.	Percentage Yield of Fat or Oil.
Alligator pear or Avoiado	*Persea gratissima*, Gaert.	*Laurineæ*	West Indies, Brazil	28 to 30
Almond	*Amygdalus communis*, L.	*Amygdaleæ*	Mediterranean	45 to 55
Anda	*Anda Gomesii*, Juss.	*Euphorbiaceæ.*	Brazil.	30 to 35
Apple seed	*Pyrus Malus*, L.	*Pomaceæ*	Europe.	17 to 19
Artichoke	*Cynara cardunculus*, L.	*Compositæ.*	Mediterranean	20 to 22
Bassia fat, fulwa butter	*Bassia butyraceo*, Roxb.	*Sapoteæ*	Himalaya, East Indies.	50 to 52
Becuiba tallow	*Myristica bicuhyba*, Mart.	*Myristicaceæ.*	Brazil	70 to 71
Beechnut	*Fagus sylvatica*, L.	*Cupuliferæ*	Europe	shelled, 43 to 45 unshelled, 27 to 29
Belladonna (Night shade) seed	*Atropa belladonna*, L.	*Solaneæ*	Europe	27 to 28
Ben	*Moringa oleifera*, Lamark.	*Caesalpiniaceæ*	India, Egypt.	35 to 36
Betel nut, Areca nut	*Areca catechu*, L.	*Palmæ.*	East Indies	14 to 16
Borneo tallow (fever nuts)	*Hopea macrophylla*, Vris.	*Dipterocarpeæ*	Sunda Island	45 to 50
Bur.	*Arctium Lappa*, L.	*Compositæ.*	Europe	19 to 20
Bur.	*Lappa major*, D. C.	*Compositæ.*	Europe	30 to 32
Cacao butter.	*Theobroma cacao*, L.	*Büttneriaceæ*	Central America	45 to 47
Calabar bean	*Calophyllum Calaba*, Wild.	*Clusiaceæ*	Antilles	62 to 65
Camelina seed	*Camelina sativa*, L.	*Cruciferæ*	Europe	31 to 34
Camul	*Mallotus Phillipensis*, Müll.	*Euphorbiaceæ*	Abyssinia, India	20 to 24
Candle nut (Bankul nut)	*Aleurites moluccana*, Wild.	*Euphorbiaceæ*	South Sea Islands.	62 to 64
Cashew nut.	*Anacardium occidentale*, L.	*Cassuvieæ*	West Indies, Brazil	40 to 45
Cass weed (shepherd's burse)	*Capsella bursa pastoris*, L.	*Cruciferæ*	Europe	31 to 34
Castor	*Ricinus communis*, L.	*Euphorbiaceæ.*	East Indies	Indian, 51 to 53 American, 46 to 49
Centaury	*Centaurea sonchifolia*, L.	*Compositæ.*	Western Europe	27 to 28
Ceylon oak (Nagkasur)	*Mesua ferrea*, L.	*Clusiaceæ*	Java, Ceylon.	39 to 40
Charlock seed	*Sinapis arvensis*, L.	*Cruciferæ*	Europe	31 to 33
Chaulmoogra	*Gynocardia odorata*, R. Br.	*Bixineæ*	East Indies	30 to 32
Cherry seed	*Prunus Cerasus*, L.	*Amygdaleæ*	Europe	35 to 36

TABLE OF THE EXTRACTIVE CONTENT OF FAT IN VARIOUS SEEDS AND FRUITS.—*Continued.*

Name of Oil, etc.	Botanical Name of Plant from which derived.	Family of Plants.	Native Country.	Percentage Yield of Fat or Oil.
Chinese tallow	*Stillingia sebifera*, Juss.	*Euphorbiaceæ*	China, Punjab	37 to 39
Chironji	*Buchanania latifolia*, W. A.	*Anacardiaceæ*	Malabar	40 to 45
Cocoa nut	*Cocos nucifera*, L.	*Palmæ*	Tropics	40 to 45
Colocynth (bitter apple)	*Citrullus colocynthidis*, L.	*Cucurbitaceæ*	Arabia, India	18 to 20
Colza	*Brassica campestris*, L.	*Cruciferæ*	Europe	33 to 43
Combo nut	*Myristica gabonensis*, Aubr.	*Myristicaceæ*	West Africa	60 to 64
Corn poppy	*Papaper rheas*, L.	*Papaveraceæ*	Europe	61 to 65
Cotton seed	*Gossypium herbaceum*, L.	*Malvaceæ*	Asia, Africa, America	24 to 26
Coula nut	*Coula edulis*, Bail.	*Terebinthinæ*	West Africa	35 to 46
Crabwood nut (Carapa nut)	*Carapa guyanensis*, Aubl.	*Meliaceæ*	Guiana, Brazil	65 to 70
Crabwood nut (Carapa nut)	*Carapa Touloucouna*, Perch.	*Meliaceæ*	Senegal	50 to 60
Cress seed	*Lepidium sativum*, L.	*Cruciferæ*	Europe	23 to 25
Croton	*Croton tiglium*, L.	*Euphorbiaceæ*	East Indies	Shelled, 53 to 56
Cucumber seed	*Cucumis sativus*, L.	*Cucurbitaceæ*	East Indies	25 to 26
Cyperus	*Cyperus esculentus*. L.	*Cyperaceæ*	Mediterranean	20 to 23
Dandelion	*Paraxacum leontopodium*, J.	*Compositæ*	Europe	27 to 28
Dika fat	*Mangifera gabonensis*, Aubr.	*Anacardiaceæ*	West Africa	60 to 64
Dragonshead	*Dracocephalum moldavicum*	*Labiatæ*	South-eastern Europe	21 to 23
Feuillia	*Feuillea cordifolia*, L.	*Cucurbitaceæ*	Brazil	55 to 60
Gambo hemp seed	*Hibiscus cannabinus*, L.	*Malvaceæ*	India	17 to 18
Gamboge	*Garcinia pictoria*, Roxb.	*Clusiaceæ*	India	24 to 25
Gilla, or Gardas seed	*Entada scandens*, Benth.	*Mimoseæ*	Bengal	30 to 32
Goa butter (Kokum fat)	*Garcinia indica*, Chois.	*Clusiaceæ*	East Indies	22 to 25
Grape seed	*Vitis vinifera*, L.	*Ampelideæ*	Asia	11 to 12
Hazel nut	*Corylus avellana*, L.	*Cupuliferæ*	Europe	50 to 60
Hemp seed	*Cannabis sativa*, L.	*Urticaceæ*	Asia	30 to 35
Hesperis	*Hesperis matronalis*, L.	*Cruciferæ*	Southern Europe	28 to 30
Hickory nut	*Carya alba*, Mich.	*Juglandeæ*	North America	29 to 30
Holly seed	*Ilex aquifolium*, L.	*Aquifoliaceæ*	Europe	25 to 27

TABLE OF THE EXTRACTIVE CONTENT OF FAT IN VARIOUS SEEDS AND FRUITS.—*Continued.*

Name of Oil, etc.	Botanical Name of Plant from which derived.	Family of Plants.	Native Country.	Percentage Yield of Fat or Oil.
Horned poppy seed	*Glaucium luteum*, L.	*Papaveraceæ*	Middle Europe	30 to 35
Horse chestnut	*Aesculus hippocastanum*, L.	*Hippocastaneæ*	Persia, India	6 to 8
Hyoscyamus (henbane) seed	*Hyoscyamus niger*, L.	*Solaneæ*	Europe	35 to 37
Illoopa or elloopa butter	*Bassia longifolia*, Roxb.	*Sapoteæ.*	East Indies	50 to 55
Indian cress seed	*Tropaeolum majus*, L.	*Tropaeoleæ*	South America	46 to 50
Ingo	*Parkia biglandulosa*, R. Br.	*Mimoseæ.*	West Africa	18 to 20
Japanese wax	*Rhus succedanea*, L.	*Cassuvieæ*	China, Japan	22 to 23
Java almond	*Bursera paniculata*, L.	*Amyrideæ.*	Molucca	40 to 42
Karanja butter (Ponga butter)	*Pongamia glabra*, Vent.	*Papilionaceæ*	India	34 to 36
Koëme (Castanha nut)	*Telfairia pedata*, Hook.	*Cucurbitaceæ*	Africa, Madagascar	33 to 35
Kopak (common bombax or wool tree seed)	*Bombax pentandrum*, Roxb.	*Malvaceæ*	India	30 to 32
Lallemantia	*Lallemantia iberica*, Fisch. and M.	*Labiatæ.*	Persia, Kurdistan	29 to 30
Laurel butter	*Laurus nobilis*, L.	*Laurineæ*	Southern Europe	24 to 26
Lentiscus	*Pistacia lentiscus*, L.	*Cassuvieæ*	Italy, Greece	44 to 45
Lettuce seed	*Lactuca oleifera*, L.	*Compositæ.*	Europe	37 to 38
Linden seed	*Tilia macrophylla*, L.	*Tiliaceæ*	Europe	25 to 28
Linseed	*Linum usitatissimum*, L.	*Lineæ.*	The East	38 to 40
Macaja butter	*Cocos aculeata*, Jaqu.	*Palmæ*	Brazil, West Indies	60 to 65
Madia	*Madia sativa*, Molin	*Compositæ.*	Chili.	32 to 33
Mafura tallow	*Mafureira oleifera*, Best	*Meliaceæ.*	Mozambique	60 to 65
Mahwa butter	*Bassica latifolia*, Roxb.	*Sapoteæ.*	East Indies	50 to 55
Maize.	*Zea mais*, L.	*Gramineæ*	America.	6 to 10
Mary thistle	*Silybum marianum*, L.	*Compositæ.*	Europe	25 to 26
Musk melon seed	*Cucurbita melo*, L.	*Cucurbitaceæ*	West Africa	30 to 32
Mustard seed (white)	*Sinapis alba*, L.	*Cruciferæ*	Europe	25 to 26
Mustard seed (black)	*Sinapis nigra*, L.	*Cruciferæ*	Europe	31 to 33
Mustard seed (Russian)	*Sinapis juncea*, L.	*Cruciferæ*	Russia	28 to 30

TABLE OF THE EXTRACTIVE CONTENT OF FAT IN VARIOUS SEEDS AND FRUITS.—*Continued.*

Name of Oil, etc.	Botanical Name of Plant from which derived.	Family of Plants.	Native Country.	Percentage Yield of Fat or Oil.
Nettle seed	*Urtica dioica*, L.	*Urticeæ*	Europe	30 to 32
Niam fat	*Lophira alata*, Schw.	*Dipterocarpeæ*	Africa	44 to 45
Nicker seed (Bonduc nut)	*Cæsalpinia bonducella*, Roxb.	*Cæsalpinaceæ*	Tropics	24 to 25
Niger (Ramtil)	*Guizotia oleifera*, D. C.	*Compositæ*	Abyssinia, India	40 to 45
Nimb, or Kohomba	*Melia azedarach*, L.	*Meliaceæ*	India	50 to 60
Nutmeg	*Myristica moschata*, Thunb.	*Myristicaceæ*	Molucca	38 to 40
Ochoco	*Dryobalanops guineensis*, Col.	*Dipterocarpeæ*	Guinea	61 to 63
Ocuba (erroneously called wax)	*Myristica ocuba*, Humb. and B.	*Myristicaceæ*	Brazil	20 to 25
Olive	*Olea europaea*, L.	*Oleaceæ-ligustrin*	Southern Europe	Pericarp, 40 to 60 Kernels, 12 to 15
Orange	*Citrus aurantium*, L.	*Aurantiaceæ*	Southern Europe, Asia.	27 to 28
Otoba	*Myristica otoba*, Humb. and B.	*Myristicaceæ*	Columbia	35 to 40
Owala	*Pentaclethra macroph.*, Benth.	*Laurineæ*	West Indies, Brazil	28 to 30
Palas tree, or Dhak-kino tree.	*Butea frondonsa*, Roxb.	*Papilionaceæ*	India	24 to 26
Palm	*Elais guineensis*, Jacqu. *Elais melanococca*, Gaertn.	*Palmæ*	West Africa South America	Pericarp, 65 to 72 Kernels, 45 to 50
Para nut (Brazil nut)	*Bertholletia excelsa*, Humb.	*Myrtaceæ*	South America	66 to 67
Parapou palm	*Guilielma speciosa*, Marb.	*Palmæ*	South America	30 to 32
Peach kernel	*Prunus persica*, Benth. and Hook	*Amygdaleæ*	Persia	46 to 48
Peanut (ground nut)	*Arachis hypogaea*, L.	*Cæsalpiniaceæ*	India, Western Africa.	43 to 45
Pear seed	*Pyrus communis*, L.	*Pomaceæ*	Europe	18 to 20
Pine seed	*Pinus abies*, L. (*Picea vulg.*, Lam.)	*Coniferæ*	Europe	25 to 30
	Pinus picea, L. (*Abies pectinata*, D. C.)	*Coniferæ*	Europe	32 to 33
	Pinus pinea, L.	*Coniferæ*	Southern Europe	44 to 48
Piney tallow (Malabar tallow)	*Vateria indica*, L.	*Dipterocarpeæ*	East Indies	—
Pistachio nut	*Pistacia vera*, L.	*Cassuvieæ*	Southern Europe	51 to 53

TABLE OF THE EXTRACTIVE CONTENT OF FAT IN VARIOUS SEEDS AND FRUITS.—*Continued.*

Name of Oil, etc.	Botanical Name of Plant from which derived.	Family of Plants.	Native Country.	Percentage Yield of Fat or Oil.
Poon seed.	*Calophyllum inophyllum*, L.	*Clusiaceæ*	India	60 to 62
Poppy seed	*Papaver somniferum*, L.	*Papaveraceæ.*	Asia Minor	Blue, 48 to 50 White, 41 to 45
Prickly poppy seed	*Argemone mexicana*, L.	*Papaveraceæ.*	Mexico, West Indies	25 to 30
Prune kernel	*Prunus domestica*, L.	*Amygdaleæ*	Europe	40 to 42
Pumpkin seed.	*Cucurbita pepo*, L.	*Cucurbitaceæ*	The East	25 to 26
Purgir nut.	*Curcas purgans*, Endl.	*Euphorbiaceæ.*	West Indies, S. America	shelled, 55 to 57
Radish seed	*Raphanus sativus oleiferus*, L.	*Cruciferæ*	China	45 to 50
Rambutan tallow.	*Niphelium lapaccum*, L.	*Sapindaceæ.*	China, Sunda Island	40 to 45
Rape seed.	*Brassica napus*, L.	*Cruciferæ*	Europe	35 to 43
Rutabaga (Swedish turnip) seed.	*Brassica napobrassica*, Miller.	*Cruciferæ*	Sweden	38 to 40
Safflower seed.	*Carthamus tinctorius*, L.	*Compositæ.*	Egypt, India	30 to 32
Sapucaja nut	*Lecythis ollaria*, L.	*Myrtaceæ*	Brazil, Guiana	40 to 42
Scotch fir seed	*Pinus sylvestris*, L.	*Coniferæ.*	Middle & North. Europe	28 to 30
Sea-kale seed	*Crambe maritima*, L.	*Cruciferæ*	Europe	32 to 35
Sesamé	*Sesamum orientale*, L.	*Bignoniaceæ.*	India, Levant, etc.	50 to 57 from the Antilles, 51 to 53 from Bombay, 50 to 52 from the Levant, 54 to 56 from Egypt, 55 to 57 from Pondicherry, 50 to 52
Shea butter (Galam butter)	*Bassia Parkii*, D. C.	*Sapoteæ.*	Tropical West Africa	49 to 52
Sierra Leone butter.	*Pentadesma butyracea*, Don.	*Clusiaceæ*	Sierra Leone	59 to 62
Soap berry	*Sapindus emarginatus*, Roxb.	*Sapindaceæ.*	India	30 to 32
Souari butter	*Peckea guyanensis*, Aubl.	*Rhizoboleæ*	Guiana and Brazil	61 to 63
Spindle nut	*Evonymus europaeus*, L.	*Celastrineæ*	Middle Europe	44 to 45
Spurge	*Euphorbia lathyris*, L.	*Euphorbiaceæ.*	Southern Europe	43 to 46
Stinking bean	*Sterculia foetida*, L.	*Sterculiaceæ*	West and East Indies	28 to 30

TABLE OF THE EXTRACTIVE CONTENT OF FAT IN VARIOUS SEEDS AND FRUITS.—*Concluded.*

Name of Oil, etc.	Botanical Name of Plant from which derived.	Family of Plants.	Native Country.	Percentage Yield of Fat or Oil.
Stramonium seed	*Datura stramonium*, L.	*Solaneæ*	Europe	25 to 27
Sunflower seed	*Helianthus annuus*, L.	*Compositæ*	Mexico, Peru	21 to 22
Tambor	*Omphalea triandra*	*Euphorbiaceæ*	West Indies	39 to 41
Tangkallak fat	*Cylicodaphne sebifera*, Bl.	*Laurineæ*	Java	40 to 45
Tea seed	*Camellia oleifera*, Ab.	*Camelliaceæ*	China	43 to 45
Thistle	*Onopordum acanthium*, L.	*Compositæ*	Europe	30 to 35
Tobacco seed	*Nicotiana rustica*, L.	*Solaneæ*	America	38 to 40
Tung	*Aleurites cordata*, Müll.	*Euphorbiaceæ*	China, Cochin China	40 to 41
Turnip seed	*Brassica rapa*, L.	*Cruciferæ*	Europe	35 to 40
Ungnadia	*Ungnadia speciosa*, Endl.	*Hippocastaneæ*	Mexico	9 to 10
Virola tallow	*Virola sebifera*, Aubl.	*Myristicaceæ*	West Indies, Guiana	40 to 45
Wallflower seed	*Mathiola annua*, L.	*Cruciferæ*	Southern Europe	22 to 23
Walnut	*Juglans regia*, L.	*Juglandeæ*	Persia, Himalaya	63 to 65
Watermelon seed	*Cucurbita citrullus*, Wgt.	*Cucurbitaceæ*	Africa	30 to 32
Weld seed	*Reseda luteola*, L.	*Resedaceæ*	Middle Europe	30 to 32
Wild radish seed	*Raphanus raphanistrum*, L.	*Cruciferæ*	Europe	35 to 40
Xymenea	*Xymenea gabonensis*, R.	*Terebinthinæ*	West Africa	60 to 70

TABLE OF EXTRACTIVE WAX. CONTENT IN VARIOUS PLANTS.

Botanical Name.	Common Name.	Family of Plants.	Native Country.	Percentage Yield of Fat or Oil.
Balanaphora species	Spadiceous plants.	*Balanophoreæ.*	Java.	—
Brosimum galactodendron, Kunth.	Cow tree	*Artocarpeæ*	South America.	—
Ceroxylon andicola, H. and B.	Wax palm.	*Palmæ.*	Cordilleras.	—
Copernicia cerifera, Mart.	Carnauba palm	*Palmæ.*	Brazil.	—
Ficus ceriflua, Bl.	Wax-fig tree	*Artocarpeæ*	Java, Ceylon	—
Fougiera splendens	Ocatilla	*Tamariscineæ*	Mexico	—
Langsdorffia hypogaea, Mart.	Langsdorffia	*Balanophoreæ*	Brazil.	—
Myrica cerifera, L.	Bayberry	*Myriaceæ*	North America.	—
Myristica Ocuba, H. and B.	Ocuba nutmeg	*Myristicaceæ.*	Brazil.	yield glycerides, and are found under fats and oils.
Rhus succedanea, L.	Japanese wax sumach	*Cassuvieæ*	China, Japan	

The following table presents a general view of the seeds and fruits richest and poorest in oil:

Names of Seeds and Fruits.	Botanical Name of Plants from which derived.	Percentage of Oil.
Para nuts	*Bertholletia excelsa*	66 to 67
Castor beans	*Ricinus communis*	50 to 65
Hazel nuts	*Corylus avellana*	50 to 60
Poppy seed	*Papaver somniferum*	48 to 50
Almonds, sweet	*Amygdalus communis*	45 to 55
Almonds, bitter	*Amygdalus communis*	40 to 50
Cacao seed	*Theobroma cacao*	45 to 47
Cashew nuts	*Anacardium occidentale*	40 to 50
Peanuts	*Arachis hypogaea*	40 to 50
Sesamé seed	*Sesamum orientale*	40 to 50
Radish seed	*Raphanus sativus*	40 to 50
Walnuts	*Juglans regia*	40 to 50
Rape seed	*Brassica campestris*	35 to 45
Spring rape	*Brassica napus ol. annua*	35 to 40
Fall rape	*Brassica napus ol. biennis*	35 to 40
Turnip seed	*Brassica rapa oleifera*	35 to 40
Nutmegs	*Myristica moschata*	35 to 40
Mustard seed, white	*Sinapis alba*	30 to 35
Weld seed	*Reseda luteola*	30 to 35
Hemp seed	*Cannabis sativa*	30 to 35
Mustard seed, black	*Sinapis nigra*	30 to 33
Spurge seed	*Euphorbia lathyris*	25 to 30
Plum kernels	*Prunus domestica*	25 to 30
Charlock seed	*Sinapis campestris*	25 to 30
Camelia, or German sesamé	*Camelina sativa*	25 to 30
Linseed	*Linum usitatissimum*	25 to 30
Cress seed	*Lepidium sativum*	23 to 25
Beech nuts	*Fagus sylvatica*	27 to 29
Sunflower seed	*Helianthus annuus*	20 to 25
Pumpkin seed	*Cucurbita pepo*	20 to 25
Thistle seed	*Onopordon acanthium*	20 to 25
Cotton seed	*Gossypium herbaceum*	15 to 20
Olive kernels	*Olea europaea*	12 to 20
Apple seed	*Pyrus malus*	12 to 15
Grape seed	*Vitis vinifera*	11 to 12
Vanilla	*Vanilla aromatica*	6 to 10
Horsechestnut	*Aesculus hippocastanum*	5 to 8
Maize	*Zea mais*	6 to 8
Rye	*Secale cereale*	1.5 to 2
Wheat	*Triticum vulgare*	2 to 2.5
Barley	*Hordeum vulgare*	1 to 1.5
Mold	*Penicillium glaucum*	6
Beer yeast	*Cryptococcus cerevisiæ*	5

FATS AND OILS OF THE ANIMAL KINGDOM.

Latin Name.	Common Name.	Family.	Home.
Anas anser domest., L.	Goose	*Palmipedes*	——
Balaena mysticetus, L.	Greenland or right whale	*Balaenodea*	North Arctic Sea.
Balaenoptera boops, Fabr.	Humpback or finback whale	*Balaenodea*	Greenland.
Bos taurus, L.	Ox (butter, tallow, tallow oil, marrow, neat's foot oil)	*Ruminantia*	In all countries.
Chenodelphinus rostratus, Br.		*Balaenodea*	In all oceans.
Clupea species	Herring, sardine, anchovy, menhaden	*Clupeacea* (*Abdominales*)	Atlantic Ocean, Baltic.
Delphinus globiceps, Lam.	Black dolphin, black fish	*Cetacea*	Arctic Ocean.
Delphinus phocaena, L.	Common porpoise	*Cetacea*	Atlantic Ocean.
Engraulis encrasicholus, Cuv.	Anchovy	*Clupeacea.*	Japan.
Equus caballus, L.	Horse	*Solidungula*	——
Gadus morrhua, L.	Cod fish.	*Gadini*	Baltic, North Sea, Norwegian coast.
Gallus domesticus, L.	Domestic fowl	*Galinæ*	——
Merlangus carbonarius, Cuv.	Pollock, coal fish	*Gadini*	Baltic, North Sea.
Ovis aries, L.	Sheep (tallow, neat's foot oil).	*Ruminantia.*	——
Phoca species	Seals	*Pinnipedia.*	——
Physeter macrocephalus, L.	Sperm whale (sperm oil, spermaceti)	*Cetacea*	In all oceans.
Raja Clavata, L.	Ray	*Rajacei*	Coasts of Europe.
Squalus maximus, L.	Shark	*Plagiostomi.*	In all oceans.
Sus scrofa, L.	Hog (lard and lard oil)	*Pachydermata setigera*	——
Taleichtys pacificus, Gerard.	Oulachan or candle fish	*Salmonidæ*	British North America, Alaska.
Trichechus rosmarus, L.	Walrus	*Pinnipedia.*	Northern Arctic seas.

WAXES OF THE ANIMAL KINGDOM.

Latin Name.	Common Name.	Family.	Home.
Apis melifera, L.	Bee	*Hymenoptera*	——
Coccus ceriferus, Fabr.	Chinese wax insect	*Hemiptera*	China.
Ovis aries, L.	Sheep (wool grease).	*Ruminantia*	——
Physeter macrocephalus, *L.*	Sperm whale.	*Cetacea*	In all oceans.

CHAPTER III.

FORMATION OF FATS AND OILS.

THE investigations regarding the formation of fats in the cells of plants and in the animal body may be considered finished. In the plant the fat is formed in the tissues in which it occurs, and only rarely penetrates, in a manner not known, from its place of production, and covers the organs in a more or less dense layer, as, for instance the seeds of *Stillingia sebifera*, which yield the Chinese tallow of commerce.

The organic substances of the vegetable kingdom are formed —with the frequent co-operation of other separate inorganic elements, such as nitrogen, sulphur, phosphorus, etc.—from carbonic acid and water, oxygen being at the same time separated.

$$\underset{\text{6 molecules carbonic acid}}{6\,CO_2} + \underset{\text{5 molecules water}}{5HOH} = \underset{\text{1 molecule starch}}{C_6H_{10}O_5} + \underset{\text{12 molecules oxygen}}{12O}$$

$$\underset{\text{1 molecule starch}}{C_6H_{10}O_5} + \underset{\text{1 molecule water}}{HOH} = \underset{\text{1 molecule glucose}}{C_6H_{12}O_6}$$

$$\underset{\text{12 molecules carbonic acid}}{12CO_2} + \underset{\text{11 molecules water}}{11HOH} = \underset{\text{1 molecule cane sugar}}{C_{12}H_{22}O_{11}} + \underset{\text{24 molecules oxygen}}{24O}$$

The conversion of the carbo-hydrates, such as starch, etc., into fat is physiologically of great importance. The carbo-hydrates are compounds of carbon with hydrogen and oxygen in the proportion to form water. From the chemical standpoint the formation takes place as follows:

$$\underset{\text{10 molecules glucose}}{10C_6H_{12}O_6} = \underset{\text{1 molecule stearin}}{C_3H_5'''(C_{18}H_{35}O_2)_3} + \underset{\text{5 molecules water}}{5HOH} + \underset{\text{43 molecules oxygen.}}{43O}$$

This mode of formation of the fats also corresponds with the fact that all seeds rich in fat, for instance, rape seed, before their maturity are filled with starch granules, which in ripening, however, disappear in the same degree as the quantity of fat oil increases; and *vice versa*, in the germination of oil seeds, for instance, rape seed, beech nuts, pine seed, etc., transitory starch, which very soon predominates in the germinating parts appears in a few days, while the fat oil disappears.

The starch in the chlorophyl-nucleus, however, is not directly produced from carbonic acid and water, but according to the opinions prevailing at present, is formed in the green chlorophyl-granules with the co-operation of sun light, first from carbonic acid = CO_2, with the separation of oxygen, carbon monoxide = CO, which by the absorption of 2 atoms of hydrogen from split water is converted into formaldehyde CH_2O.

$$\left.\begin{array}{ccccc} CO_2 & - & O & = & CO \\ \text{carbonic acid} & & \text{oxygen} & & \text{carbon monoxide} \\ HOH & - & O & = & HH \\ \text{water} & & \text{oxygen} & & \text{hydrogen} \end{array}\right\} = \begin{array}{l} CH_2O \\ \text{1 molecule formaldehyde.} \end{array}$$

By the influence of the cell-activity of the protoplasm several molecules of the formaldehyde are then condensed, and water being simultaneously separated, starch, sugar or inulin —$C_6H_{10}O_5$— is, according to circumstances, formed.

By the condensation of 6 molecules formaldehyde, CH_2O, glucose, or with the separation of water, starch may be formed.

$$\frac{6CH_2O}{\text{6 molecules formaldehyde}} = \frac{C_6H_{12}O_6}{\text{1 molecule glucose}}$$

$$\frac{6CH_2O}{\text{6 molecules formaldehyde}} = \frac{C_6H_{10}O5}{\text{1 molecule starch}} + \frac{H_2O}{\text{1 molecule water.}}$$

The decomposition of glucose to fat or stearin may now be supposed to take place in the manner above indicated, or else that by the condensation of formaldehyde —CH_2O— not only starch and glucose, but also glyceric and fatty acids may be formed.

By treble condensation this aldehyde in the presence of hydrogen may yield glycerin —$C_3H_5'''(OH)_3$, and from the latter by condensation under reducing influence, oleic acid and stearic acid may be formed.

$$\frac{3CH_2O}{\text{3 molecules formaldehyde}} + \frac{2H}{\text{hydrogen}} = \frac{C_3H_5'''(OH)_3}{\text{glycerin}}$$

$$\frac{C_{18}H_{38}O_{13}}{\text{hexaglycerin}} - \frac{HOH}{\text{water}} - \frac{10O}{\text{oxygen}} = \frac{C_{17}H_{35}.CO.OH}{\text{stearic acid}}$$

$$\frac{C_{18}H_{38}O_{13}}{\text{hexaglycerin}} - \frac{2HOH}{\text{water}} = \frac{9O}{\text{oxygen}} = \frac{C_{17}H_{33}.CO.OH}{\text{oleic acid}}$$

$$\frac{C_3H_5(OH)_3}{\text{glycerin}} + \frac{(C_{17}H_{33}.CO.OH_3)}{\text{oleic acid}} = \frac{3HOH}{\text{water}} + \frac{(C_{17}H_{33}.COO)_3C_3H_5}{\text{olein.}}$$

This hypothesis is fully justified by the fact that in the plants the fatty acids are always fixed on glycerin.

Pringsheim, according to a method of his own, which he calls " microscopic photo-chemistry," has shown that in an intense light, by means of a heliostat and a lens of 60 millimeters diameter, the chlorophyl is entirely destroyed, that this destruction takes place in all colors: red—behind a solution of iodine in bisulphide of carbon; green—behind a solution of copper chloride, and blue—behind a solution of cupric sulphate, and that a peculiar body previously not known is found in the vegetable cell. To this body, called *hypochlorin* by Pringsheim, the term *chlorophyllan* has later on been applied. To make it appear it is only necessary to place a chlorophyl-green tissue—no matter of which division of phenogamic or cryptogamic plants—in dilute hydrochloric acid for about 12 to 24 hours. The hypochlorin then appears in the form of very minute, viscous drops, becoming larger by accumulation, or in masses of semi-liquid consistency, which gradually form into indistinct nests, and finally grow into indistinct crystalline nests. According to all micro-chemical characteristics, this body is an oil-like substance impregnating the elementary matter of the chlorophyl bodies. It is soluble in alcohol, ether, oil of turpentine and benzole, and insoluble in water and salt solutions.

Of all the constituents of the cell, hypochlorin is most readily combustible in light and oxygen; in the presence of oxygen it is even sooner consumed by an intense light than the chlorophyl itself. From the ordinary intensities of light under which plants grow, the hypochlorin is sufficiently protected by the chlorophyl. The latter is a porous body, in the pores of which the hypochlorin and oil are collected. It is certain that the hypochlorin is closely connected with the fat, volatile and wax-like bodies, and since many seeds at an early stage contain chlorophyl, a small portion of their fats may not improperly be considered a direct product of assimilation. It is also certain that on account of their inability to pass membranes moistened with water, the fats cannot flow from the plant to the seed, and must, therefore, be formed from substances present in the seed itself.

In the vegetation of fungi—mold, yeast, etc.—fat, according to Carl v. Naegeli's investigations, may be produced in a similar manner, as in the animal body, by the splitting or decomposition of albuminous substances, since with a constant quantity of cellulose the quantity of fat increases from 18 to 50 per cent., while the quantity of cellulose decreases from 42 to 16 per cent. Hoppe-Seyler, more than 30 years ago, considered this mode of the formation of fat in plants and animals probable in opposition to Liebig's theory prevailing at that time, which ascribed the formation of animal fat to the conversion of the carbo-hydrates of the nutriment.

According to the more recent investigations of C. Voit and others, the formation of the animal fat has to be sought for not in the carbo-hydrates, but in the albumen subject to change of substance. The albuminous substances of the nutriment furnish nearly the sole material for the new formation of fat, and especially the portion of the dissolved albuminous substances which is decomposed in the body by oxidation and split into urea, creatin, uric acid, etc., fat, carbonic acid and water being separated.

According to Henneberg, 100 parts of anhydrous albumin may yield by splitting 33.5 parts urea and 51.4 parts fat.

$$\frac{2(C_{12}H_{112}N_{18}O_{22}}{\text{2 molecules albumin}} + \frac{139O}{\text{139 molecules oxygen}} = \frac{18CO(NH_2)_2}{\text{18 molecules urea}} +$$

$$\frac{(C_{17}H_{35}COO)_3C_3H_5'''}{\text{stearin}} + \frac{69CO}{\text{69 molecules carbonic acid}} + \frac{21HOH}{\text{21 molecules water.}}$$

The urea is removed from the blood by the kidneys and separated with the urine, while the fat formed by the decomposition of the albumin serves for augmenting the fat of the body.

The theory of the formation of animal fat from albuminous substances is further sustained:

1. By the formation of *adipocire* in dead animal bodies, this fat occupying in the body all former soft parts and occasionally showing still the form of the former tissue-parts; hence the albuminous substances of the muscles have been converted into fat.

2. If pulverized meat carefully freed from fat by repeated boiling with ether is subjected to putrefaction, higher fatty acids—oleic acid—amounting to 3 per cent. of the dry albuminous substance are formed. Serum-albumin subjected to putrefaction also yields considerable quantities of fatty acid.

3. By the absolute increase in the content of fat of the heart in the fatty degeneration of the latter with considerable general emaciation.

4. Under other pathological conditions fat in large quantities is formed and accumulates in the body; for instance, in fatty degeneration of the liver, obesity, etc.

It is certain that albuminous substances as well as carbohydrates assist in the formation of fats and oils in the vegetable, as well as the animal body.

5. By the fact that cows fed on fodder rich in albuminous substances yield milk richer in fat.

6. By observations regarding the ripening of cheese, which have shown that the chemical process taking place thereby is characterized by constant considerable augmentation of fat, and decrease of casein.

Utility and Uses of Fatty Bodies.

The functions of the fat in organisms are of various kinds, it possessing

1. An anatomico-mechanical function since it accumulates in the form of the so-called fatty tissue, and serves as a bolster,

cushion, and distributer of pressure; further for filling up empty spaces.

2. A physico-physiological function, since it possesses but slight capacity for conducting heat, counteracts the radiation of heat from the animal body, and makes the parts of the body supple.

3. A chemico-physiological function. By the activity of the animal cells the fats in the body are readily oxidized and consumed to carbonic acid and water. They thus form one of the most important means of respiration, and furnish the principal material for excitation and maintenance of the animal heat. (The heat produced in the body of a healthy person by the introduction of nutriment, especially of the fat, during twenty-four hours, if it remained in the body and were not yielded to the exterior, would suffice to raise the temperature of the body during this time to 121° F. The heat produced in the course of one year would suffice to heat 200 to 250 cwt. of water from the freezing point to the boiling point.)

There can be no doubt of the great importance of fat for the nourishing processes, but a thorough comprehension of the causal circumstances is still wanting. Virtually there are two facts which may be considered settled. The alimentary fat, as far as it passes into the fluids of the body, on the one hand, serves directly for replacing the fatty tissue consumed in the processes taking place in the change of matter; and, on the other, it must be considered an excellent economic agent, since by its introduction the consumption of the albumen of the body is reduced to a far greater degree than is the case with the introduction of the same quantity of carbo-hydrates or gelatin.

It has been shown that the alimentary fat is directly assimilated, *i. e.* enters directly as such into the fatty body and serves for direct augmentation. Thus the fat and meat of chickens, pigeons, ducks, geese, etc., acquires a varnish-like odor and taste when these animals are fed with linseed. The lard of hogs fed with linseed cake acquires a similar taste and odor, and that of hogs fed on fishes, a train-oil taste and odor.

However, the properties of the fats are also changed, they acquiring properties of the alimentary fat as has been shown in lard. This behavior is of great importance, and has to be taken into consideration in examining samples of fat—see cotton-seed oil and lard.

The digestion of the fats is effected by the gastric juice and the gall. The resorption of the alimentary fat in the intestinal canal takes place as neutral fat in the form of an emulsion, or after previous splitting by the pancreatic fluid into fatty acids and glycerin. The alkalies combine with the fatty acids to soaps, the latter at the same time converting the undecomposed fat into an emulsion. This emulsion by the activity of the intestinal epithelium passes into the entrances of the chyle ducts which are anatomically connected with the epithelium. In this manner the resorption of soaps and non-saponified fat is effected, the process being very likely promoted by the gall.

The fats are of great importance in the household, in the trades, arts, medicine, etc. In the latter they serve for the preparation of salves, most of which are a mixture of oil, lard and wax, or of tallow, lanolin, etc., with additions; further for plasters, pomades, etc.

For a long time it was the general belief that each variety of fat possessed special medicinal properties and powers, and various fats were used for different diseases, but it is scarcely necessary to say that this old belief has been exploded. All fats and oils, when thoroughly purified, have the same properties. There are but a few oils which possess special properties, for instance, castor oil and croton oil, which serve as a purgative, and cod-liver oil which, on account of its content of acid and small content of iodine, is used as remedy for scrofula and pulmonary consumption.

In the trades, oils and fats serve for the manufacture of soap and varnishes, further for coating a number of bodies to render them softer, smoother, or more flexible, or to protect them from the action of the air. They are also used as lubricants for machines, in the preparation of cements, etc.

CHAPTER IV.

PHYSICAL PROPERTIES OF FATS AND OILS AND PHYSICAL EXAMINATIONS—GENERAL PHYSICAL PROPERTIES OF FATS, OILS AND WAXES.

TO the general physical properties of fats, etc., belong only those which can be perceived by the senses, viz.: *Color*, *odor*, *taste*—organoleptic method of examination; further *specific gravity*, *consistency*, *freezing point*, *melting point*, *congealing point*, and finally *drying* of oils.

The organoleptic method is an individual method, but can be cultivated, the best examples being experienced oil-dealers and wine-merchants. The characteristic odor and taste of an oil, etc., may sometimes be more plainly brought out by very gently heating the oil in a dish with dry chloride of sodium (common salt), or in a test glass in a steam bath. The recognition of colors is also a matter of perception as well as of practice.

Odor. Cold-pressed fats and oils in a pure and fresh state are nearly all inodorous, though there are some exceptions, as palm oil, which has an agreeable odor of orris root, cacao butter, with an odor of the cacao seed, nutmeg butter with an odor of nutmegs, etc. Train-oils have a fishy smell. In time all fats, however, acquire a disagreeable odor.

Taste. Most fats and oils, when first placed upon the tongue, have no taste, their presence being perceptible only by their lubricity, but later on the mild and agreeable taste of the fresh parts of the plants is developed. Some fats, however, are remarkable for their pungent taste, for instance, carapa fat which is bitter, and the train-oils with a strong fishy taste.

The disagreeable taste of rancid fats is well known.

Rancidity is in most cases due to an oxidation of the fats which progresses at first slowly, but more rapidly later on. The fats split first into free fatty acids and glycerin, and by the absorption of oxygen various volatile fatty acids—propionic, butyric, valerianic, caproic, etc., acids—are formed from the glycerin and free fatty acids, especially from oleic acid, which impart to the rancid fats their characteristic odor and taste.

Based upon experimental investigations and observations, E. Ritsert, in 1890, established the fact that the rancidity of oils and fats is caused by a direct process of oxidation which progresses the more rapidly the greater the intensity of light to which the oil or fat is at the same time exposed. Light alone, in the absence of air or oxygen, does not possess the power of making fat rancid.

In the dark, even with the admission of air, pure fat does not become rancid in two months. The carbonic acid of the air exerts a slight influence, relatively small quantities of it being absorbed by the fat in the dark as well as in the light. However, carbonic acid does not make fat rancid, but only imparts to it a tallow-like taste.

Fats do not become rancid by bacteria, the action of ferments, or of moisture.

Inoculated bacteria die, and though they may exist upon rancid fat they perish in the presence of too much free fatty acid, for instance, upon old palm oil.

To prevent fats from becoming rancid the first condition is, according to E. Ritsert, the absolute exclusion of air. When this requirement has been fulfilled it does not matter whether the fat is exposed to the light or not. In the practice such exclusion of the air is, however, not practicable.

By treatment with water and bicarbonate of soda the rancid taste and odor of oils and fats can be partially removed.

Changes by exposure to the air. Oils and fats absorb oxygen the more rapidly the greater the surface they present to the air.

The heat which is liberated in consequence of chemical combination may, with bad conductors, for instance wool or cotton waste saturated with oil and stored in large quantities, become so great as to cause spontaneous combustion.

Simultaneously with the absorption of oxygen and constant yield of carbonic acid, various vegetable oils lose their transparency, and finally dry to a translucent, flexible, yellowish substance, dissolving with difficulty in boiling alcohol. Such oils are called *drying or siccative oils.*

The non-drying oils also are more or less changed by the action of the air. They acquire a different color, become denser and more viscous, less readily combustible, and carbonize the wicks.

Color. In a fresh state most oils are only slightly colored, castor oil being the palest. Generally speaking the color is yellowish or greenish, like that of hemp oil; train oils are reddish or brownish. The fats are generally white, cocoanut butter and piney tallow being pure white; only a few vegetable fats show a pronounced coloring.

Fresh palm oil is orange-yellow, the color, however, becoming gradually paler, so that by the time the oil has become rancid it has acquired a dirty white color. Fresh palm oil from *Astrocaryum vulgare* has a vermilion color, which loses nothing in intensity even after many years.

Solubility of fats and oils in water, alcohol, glacial acetic acid, etc. Fats and oils are generally supposed to be entirely insoluble in water. This is, however, not the case, they only dissolving with extreme difficulty. By vigorously shaking fresh purified oil with water for some time, a minute quantity of fat can be extracted from the water with ether. And just as traces of fat oil are soluble in water, so oils also disolve traces of water which evaporate at a moderate heat. Fat oils may take up as much as ½ per cent. of water without appearing turbid.

Fats and oils are readily soluble in *ether*, *chloroform*, *carbon disulphide*, *essential oils*, *benzole*, *petroleum*, *petroleum-ether*, *amyl alcohol*, *acetone*, *carbolic acid*, etc. *Tea-seed oil and camellia oil* dissolve with great difficulty in ether. *Castor oil* is almost insoluble in petroleum, petroleum-ether and heavy petroleum. With 7 volumes petroleum or 18 volumes petroleum-ether, 10 volumes of castor oil give clear mixtures; however, every further addition causes turbidity, and later on separation into two clear fluids. Petroleum absorbs only 0.460 per cent. of castor oil, and petroleum-ether 0.490 per cent. Castor oil and olive-kernel oil are miscible in all proportions with alcohol. Pine seed oil dissolves in equal parts of alcohol to a clear fluid; with a larger addition the mixture becomes turbid, only 1 part of the oil dissolving in 12 parts of alcohol. In cold alcohol of 0.800 specific gravity = 99 per cent., the rest of the oils dissolve with difficulty or are next to insoluble, for instance, candle nut oil, tea seed oil; in boiling alcohol they are more or less readily soluble. The appended table gives the quantities of alcohol which dissolve 1 part of oil:

SOLUBILITY OF FATS AND OILS IN ALCOHOL OF 0.800 SPECIFIC GRAVITY.

Names of Fats or Oils.	Alcohol.		Names of Fats or Oils.	Alcohol.	
	Cold.	Boiling.		Cold.	Boiling.
Almond	60	15	Lard	—	27
Cacao	—	4	Linseed	40	5
Camelia	68	—	Madia	30	6
Cod liver	45	6	Nut	100	60 alcohol = 100 oil
Cotton seed	75	—			
Croton	36	—	Nutmeg	—	4
Dolphin	—	1	Poppy	25	6
Hemp	30	in every proportion.	Suet (ox tallow)	—	40
			Tallow (sheep)	—	45
Japanese	—	3			

100 PARTS ALCOHOL DISSOLVE OF

Butter	1.80 per cent.	Pollock oil	3.40 per cent.
Cod liver oil	0.27 "	Rape seed oil	0.38 "
Colza oil	0.53 "	Seal oil	0.50 "
Grape seed oil	0.67 "	Sesamé oil	0.45 "
Lard	1.00 "	Shark oil	10.00 "
Linseed oil	0.65 "	Suet (ox tallow)	0.67 "
Margarin	0.30 "	Sunflower oil	0.62 "
Niger oil	1.00 "	Tallow (sheep)	0.25 "
Olive oil	0.38 "	Walrus oil	1.00 "
Peanut oil	0.52 "		

Dubois and Padé have determined the solubility of some fats and fatty acids in various solvents, and obtained the following results:

Solubility of some Fats in Alcohol and Amyl Alcohol.

Fats.	Solubilty at 53.6° F. in 100 parts.	
	Alcohol = 0.794 sp. gr.	Amyl alcohol.
Butter	1.803 parts	2.33 parts.
Lard	1.064 "	1.60 "
Margarin	0.300 "	0.39 "
Suet (ox tallow)	0.679 "	0.80 "
Tallow (sheep)	0.307 "	0.45 "
Veal fat	0.945 "	1.26 "

Solubility of some Fatty Acids in Alcohol and Benzol.

Fatty Acids (crude) from	Solubility in 100 parts.			
	Alcohol = 0.794 sp. gr.			Benzol.
	32° F.	50° F.	78.8° F.	53.6° F.
Butter	10.61 parts.	24.81 parts.	158.20 parts.	69.61 parts.
Lard	5.63 "	11.23 "	118.98 "	27.30 "
Margarin	2.37 "	4.94 "	46.06 "	13.53 "
Suet (ox tallow)	2.51 "	6.05 "	83.23 "	15.89 "
Tallow (sheep)	2.48 "	5.02 "	67.96 "	14.70 "
Veal fat	5.00 "	13.78 "	137.10 "	26.08 "

Most fats and oils are more or less soluble in glacial acetic acid=1.0562 specific gravity, rosin oil being readily soluble and mineral oil very sparingly, and according to their solubility in this solvent E. Valenta has brought the oils into three groups:

I. *Oils completely soluble at the ordinary temperature* (59° to 68° F.): Castor oil, olive kernel oil.

II. *Oils completely or nearly completely soluble at temperatures from 73.40 F. to the boiling point* (244.40° F.) *of glacial acetic acid:* Almond oil, apricot kernel oil, bone oil, cacao butter, cocoanut oil, cod-liver oil, cotton-seed oil, Illipé butter, laurel oil, nutmeg oil, olive oil, palm oil, palm kernel oil, peanut oil, pumpkin seed oil, suet (ox tallow), sesamé oil.

III. *Incompletely soluble at the boiling temperature of glacial acetic acid:* Rape seed oil, turnip seed oil, wild radish seed oil (oils of cruciferous plants).

The experiments are made by intimately mixing in a test-tube equal volumes of oil and glacial acetic acid, and exposing the mixtures to various temperatures.

To distinguish the oils of the second group, equal volumes of oil, etc., and glacial acetic acid in a test-tube are slowly heated, with shaking, until a perfectly clear solution results. The solution is then allowed to cool, and with the assistance of a thermometer placed in the fluid, the temperature is determined at which the clear solution commences to get turbid.

A hot solution of equal volumes of the following oils and glacial acetic acid=1.0562 specific gravity, becomes on an average turbid at:

Name of Oil.	° C.	° F.	Name of Oil.	° C.	° F.
Almond oil.........	110	230	Nutmeg oil	27	80.6
Apricot kernel oil ...	114	237.2	Olive oil, green.....	85	185
Bone oil	90 to 95	194 to 203	" yellow	111	231.8
Cacao butter	105	221	Palm oil...........	23	73.4
Cocoanut oil........	40	104	Palm kernel oil.....	48	118.4
Cod-liver oil...... ..	101	213.8	Peanut oil	112	233.6
Cotton-seed oil......	110	230	Pumpkin seed oil. ..	108	226.4
Illipé butter........	64.5	148	Sesamé oil.........	107	224.6
Laurel oil..........	26 to 27	78.8 to 80.6	Suet (ox tallow)....	95	203

However, the practical value of Valenta's glacial acetic acid test is apparently not very great, since considerable discrepancies exist between the results of his experiments and those of others, the following values, for instance, having been obtained by A. H. Allen* and G. H. Hurst:†

* Commercial Organic Analysis. Vol. 2, p. 26.

† Journ Soc. Chem. Industry, 1887, p. 22.

Oil.	Valenta. °F.	Allen. °F.	Hurst. °F.
Almond	230	—	—
Bottlenose	—	215.6	165.2–183.2
Butter fat	—	142.7	—
Cacao butter	221	—	—
Cocoanut	104	45.5	not turbid at 55.4
Cod-liver	213.8	174.2	149
Cotton-seed	230	194	127.4–145.4
Illipé butter	148.1	—	—
Lard	—	205.9	—
Lard oil	—	—	156.2–168.8
Laurel	78.8–80.6	104	—
Linseed	—	134.6–165.2	—
Melon seed	226.4	—	—
Menhaden	—	147.2	—
Neat's foot	—	215.6	149–185
Niger seed	—	120.2	—
Nutmeg butter	80.6	102.2	—
Oleomargarin	—	205.9	—
Olive (green)	185	—	82.4–168.8
" (yellow)	231.8	—	
Palm	73.4	181.4	not turbid at 55.4
Palm kernel	118.4	89.6	—
Peanut	233.6	188.6	161.6–197.6
Porpoise	—	104	—
Sesamé	224.6	188.6	—
Shark liver	—	221	203
Sperm	—	208.4	185
Suet (ox tallow)	203	—	—
Tallow, pressed	237.2	—	—
Tallow oil, cold pressed	—	—	116.6
Whale oil	—	100.4–186.8	118.4–159.8

Sulphur, selenium, and phosphorus are dissolved by oils, the dissolving capacity being increased by heat. On cooling, a portion of the dissolved substances re-separates, however, in a crystalline form.

Basic copper, (verdigris) and lead salts, etc., are also soluble in oils, and further, vegetable alkaloids, such as morphine, cinchonine, strychnine, etc.

Cow milk is a natural emulsion; it appears turbid because the fat—butter—floats in invisible globules in the casein solution. By standing the greatest portion of the fat separates on the surface and forms the so-called cream.

Oils shaken with alkaline carbonates also yield an emulsion which, under the name of "white bath," is used in dyeing Turkey-red.

Capillarity.—Fixed oils dropped upon paper penetrate it, making it transparent or causing what is commonly called grease stains, which do not disappear on heating. Even fats with a comparatively high melting point cause stains when heated.

Fats penetrate porous substances such as wood and leather with avidity, imparting to the latter a certain degree of softness and pliancy. They also penetrate readily the various clays and similar mineral substances, such as magnesia, etc. This property is utilized to remove grease stains from paper, wood, cloth, marble, etc., by the application of a paste of pipe-clay, fuller's earth, or magnesia and water, or alcohol or benzol. In drying the paste absorbs the fatty substance. The process of fulling cloth is also based upon this property.

Consistency and viscosity.—At an ordinary temperature the vegetable fats are fluid on account of their large content of olein, the exceptions being cocoanut oil, palm oil, cacao butter, nutmeg butter, Chinese tallow, laurel butter (bayberry fat), etc., which by reason of their content of palmitin, possess the consistency of butter. The fats from tropical regions are, as a rule, more solid than those from cold countries.

The fat of animals fed on straw and hay is more solid than that of pastured stock, it containing a preponderance of stearin.

The fat of carnivorous animals, dog fat, and the fat of birds (goose fat) is soft, also human fat, lard, butter and horse grease (from the neck of the horse).

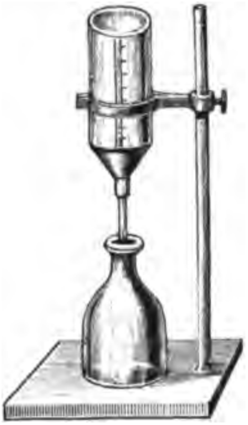
The fat of fishes (train oil, liver oil), remains fluid at an ordinary temperature, also egg oil as well as neat's foot oil from fresh feet of oxen and sheep.

The consistency of the liquid oils varies very much, castor oil being the most viscous. The value of oils for illuminating purposes depends greatly on their degree of fluidity. The latter is determined by the time required by equal quantities of oil to flow out through an aperture at the same temperature.

Various apparatuses for determining the degree of fluidity have been constructed, some of them indicating also frictional resistance.

Gustav Schuebler made experiments with a series of oils, using the simple apparatus shown in Fig. 9. It consists of a glass tube about three-quarters inch in diameter, narrowing below to about one-tenth inch in diameter. The tube is secured to a stand. The apparatus is filled with equal quantities of the separate oils and, by a watch, the time noted which the oil requires to flow out. The fluidity of water previously determined serves for comparison. In Schuebler's experiment, the results of which are given in the appended table, the action of the temperature upon the fluidity of the oils was also taken into consideration and determined at 45.5° and 59° F.

FIG. 9.



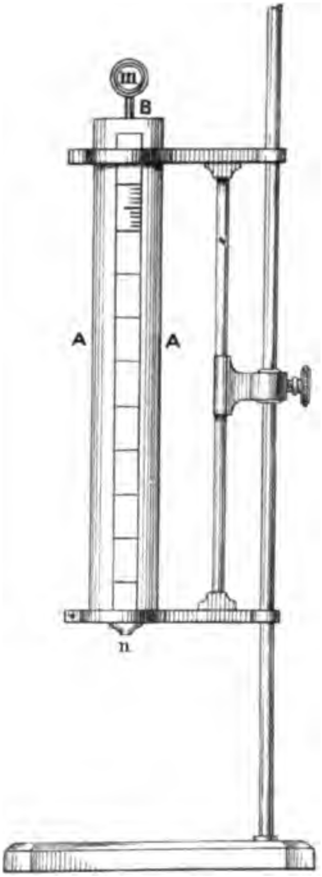
SCHUEBLER VISCOSIMETER.

Names of Oils.	Time required for flowing out, in seconds, at		Fluidity, that of water placed = 1000, at		The oil is therefore more thickly fluid than water at	
	59° F.	45.5° F.	59° F.	45.5° F.	59° F. times.	45.5° F. times.
Castor oil	1830	3390	4.9	2.6	203	377
Olive oil	195	284	46.1	31.1	21.6	31.5
Pumpkin-seed oil.	185	240	48.6	37.5	20.5	26.6
Hazel-nut oil	166	218	54.2	41.2	18.4	24.2
Colza oil	162	222	55.5	40.5	18.0	22.4
Beech-nut oil	158	237	56.9	37.9	17.5	26.3
White mustard-seed oil.	157	216	57.3	41.7	17.4	24.0
Almond oil..........	148	205	60.8	43.9	16.4	22.7
Spindle-tree oil	143	210	62.9	42.8	15.9	23 3
Radish-seed oil.	143	197	62.9	45.6	15.9	21.9
Black mustard-seed oil.	141	175	63.8	51.4	15.6	19.4
Poppy-seed oil	123	165	73.1	54.5	13.6	18.3
German-sesamé oil....	119	160	75.6	56.2	13.2	17.7
Belladonna-seed oil. ..	118	157	76.2	57.3	13.1	17.3
Sunflower-seed oil	114	148	78.9	60.8	12.6	16.4
Red-pine-seed oil.....	107	151	84.1	59.6	11.8	16.7
Cress-seed oil........	103	130	87.3	69.2	11.4	14.4
Grape-seed oil	99	128	90.9	70.3	11.0	14.2
Plum-kernel oil.	93	132	96.7	68.1	10.3	14.7
Tobacco oil..........	90	122	100.0	73.7	10.0	13.5
Walnut oil	88	106	102.2	84.9	9.7	11.8
Linseed oil..........	88	104	102.2	86.5	9.7	11.5
Hemp oil	87	107	103.4	84.2	9.6	11.9
Pitch-tree oil	85	102	105.8	88.2	9.4	11.3
Weld-seed oil........	73	96	103.7	93.7	8.0	10.7
Distilled water	9	9	1000	1000	00.0	00.0

August Vogel's viscosimeter or elaeo-pachymeter.—This instrument has been modified in so far that not the time of efflux of a certain quantity of oil can be observed, but the quantity of oil flowing out in a fixed time. This modification has the advantage that a sand-glass fixed for 30 seconds may be used.

The apparatus, Fig. 10, consists of a glass tube 1.57 inches in diameter and 13.38 inches long, terminating in a cone. The efflux-aperture is 0.59 inch in diameter and can be closed with a glass rod, *B*, the lower end *n* of which is ground in the aperture so that on raising the glass rod by means of the ring *m*, the contents of the graduated tube are emptied. By lowering the glass rod the aperture is closed and the efflux immediately stopped. As previously mentioned, the time required for the efflux is indicated by a sand-glass set exactly for 30 seconds.

FIG. 10.

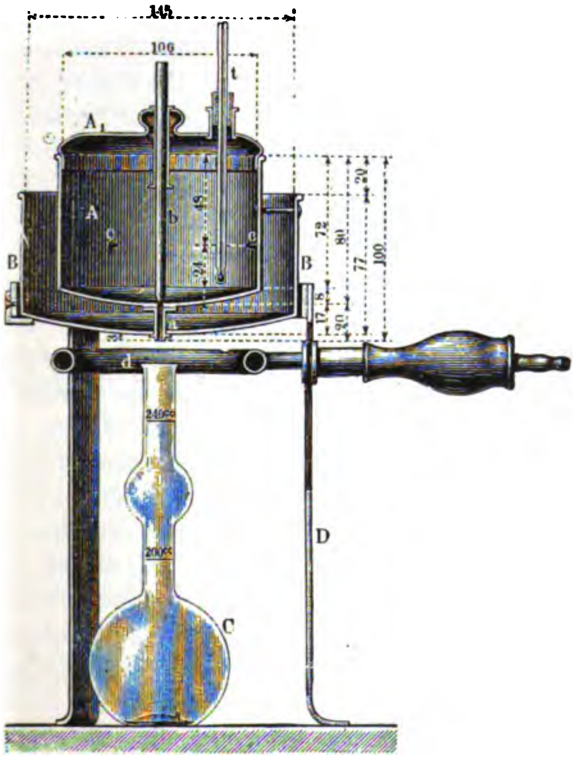


VOGEL'S VISCOSIMETER.

Prof. C. Engler calls the viscidity of oils as compared with water the *viscosity degree*, and the specific viscidity the *specific viscosity*, referred as in the determination of the specific gravity to a fixed temperature in this case to 20°C.=68° F.

Engel's Viscosimeter.—By reason of its simplicity and capability this apparatus, Fig. 11, is largely used, and is employed by all railroads in Germany, Austria-Hungary and Russia for testing the viscosity of oils. The oil-holder is shallow, in order to reduce hydrostatic pressure to a minimum. The dimensions are also accurately fixed throughout, and the outflow-orifice is of such a diameter that not too much time is required

FIG. 11.



ENGEL'S VISCOSIMETER.

in testing very thick oils. The illustration represents the latest improved form of the apparatus. *A* is a shallow brass vessel for the reception of the oil and can be closed by the cover *A*. The form and dimensions of *A* will be seen from the illustration, the figures referring to centimeters. To the conical bottom of

A is fitted the outflowing tube *a*, exactly 20 millimeters (0.78 inch) long, with a diameter on top of 2.9 millimeters (0.1142 inch) and on the bottom of 2.8 millimeters (0.1102 inch). For exact normal determinations the tube is made of platinum, and for ordinary purposes, of brass. It can be closed by the pointed, hard-wood stopper *b*, and opened by withdrawing the latter. Three marks *c* are placed at equal distances from the bottom and serve for measuring the oil, as well as for judging whether the vessel *A* stands level. Up to the marks *c* the vessel *A* must hold 240 cubic centimeters, which, with the slightly conical bottom and the dimensions given in the illustration, is actually the case. The thermometer *t* serves for reading off the temperature of the oil to be tested. The vessel *A* is surrounded by a brass jacket *BB*, open on top, and serves for the reception of water or heavy mineral oil for heating the contents of *A* to 150°C. (302° F.). To prevent the oil from cooling off too much while passing through the tube *a*, the latter projects only about 3 millimeters (0.118 inch) from the jacket *B*. For observing the temperature of the oil in the jacket *B*, a thermometer is fixed in the latter. A trevet *D* serves as a support for the whole, and besides carries the gas pipe *d*, with four burners, by means of which the oil is brought to and maintained at the proper temperature. Under the outflow tube stands the measuring flask *C* which is furnished on the neck with two marks, one at 200 cubic centimeters and the other at 240 cubic centimeters. To obviate a too great length of the neck, which would also affect the outflowing jet and impair the accuracy of the experiment, the neck is bellied.

To work with this apparatus the time has first to be determined, which is required by water of 20°C. (68°F.) running from it to fill the measuring flask *C* to the lower mark (200 cubic centimeters). The viscosity of the various oils at the different temperatures is then determined in comparison to that of water of 20°C. (68°F.), and the figure obtained is called the specific viscosity—*viscosity-degree*—of the oils.

To test the apparatus as to its accuracy, the time in seconds is determined which is required by 200 cubic centimeters of water of 20°C (68°F.) to flow from the vessel *A* filled up to the marks *c*. For this purpose the vessel *A* is rinsed out successively with small quantities of ether, alcohol, and finally of water, the outflow-tube being at the same time cleaned with a feather and a small paper wad, and the hard wood stopper *b* inserted. Exactly 240 cubic centimeters of water are then measured off in the measuring flask *C* and poured into the vessel *A*, which thereby should be filled exactly up to the mark *c*. The temperature of the water is then brought up to 20°C. (68°F.), this being done by maintaining the water or heavy mineral oil in the jacket *BB* at a uniform temperature until the thermometer *t* shows exactly 20°C. (68°F.), and the thermometer fixed in *B* differs but slightly from it. The measuring flask *C* having in the meanwhile been allowed to drain off for at least one minute, is then placed under the orifice, the hard wood stopper *b* withdrawn, and the time in seconds noted by a watch or chronometer which is required for the measuring flask *C* to be filled up to the 200 cubic centimeter mark. Before allowing the water to flow care must be taken that it is perfectly still, and especially not in rotatory motion due to previous stirring. If the apparatus is properly constructed, 50 to 55 seconds are required by the water to run out. The mean of at least three determinations, which should not vary more than 0.5 second from each other, is taken as the correct figure and placed=1. Very exact determinations should be executed in a room having as nearly as possible a temperature of 20° C. (68° F.).

In testing oils care must be taken to remove every trace of moisture from the vessel *A*, this being effected by drying and rinsing in succession with alcohol, ether and petroleum. The apparatus is finally rinsed with the oil to be tested and then filled with the latter up to the marks *c* (only thin oils can be measured like water in the measuring flask *C*.). By heating the water or heavy mineral oil in the jacket *B*, the temperature is then brought to the degree desired, and maintained at that degree for at least three minutes before allowing the oil to be tested to run out. The time required for the oil to run out is determined in the same manner as described above for testing the apparatus. The figure obtained, for instance 270 seconds, is divided by the figure of the flow of water of 20° C. (68° F.) in the same apparatus, for example, 52 seconds, which gives the specific viscosity or viscosity-degree; hence, in this case

$$\frac{270}{52} = 5.2.$$

Oils containing particles of water in suspension have to be passed, before testing, through a dry paper filter.

A viscosity-degree of 2.6 is considered by Engler the lowest limit for the usefulness of an oil for lubricating purposes—see the appended table.

VISCOSITY-DEGREES OF A FEW OILS DETERMINED BY ENGLER'S VISCOSIMETER.

Names of Oils.		Specific gravity at 59° F.	Outflow= time in seconds.	Viscosity= degree at 20° C. (68° F.)
Brown coal (lignite) tar		0.8570	73	1.40
Castor oil		0.9634	5372	103.50
Linseed oil.		0.9290	330	6.33
Mineral oil, Russian		0.9868	562	10.80
Neat's foot oil		0.9160	640	12.30
Olive oil	common	0.9165	695	13.30
	table	0.9165	676	13.00
Peanut oil.		0.9180	600	11.50
Petroleum.		0.820	57	1.10
Rape seed oil	crude.	0.9146	774	14.90
	refined.	0.9137	723	14.10
Turnip seed oil	crude.	0.9124	720	13.65
	refined.	0.9110		

Outflow-time of water=52 seconds.

After a number of experiments with Engler's viscosimeter in the technical experimental station at Berlin, the conclusion has been reached that this is the most suitable apparatus.

*Lepenau's leptometer.**—This apparatus, shown in Figs. 12 and 13, allows of a direct comparison of the viscosity of the oil to be tested with a standard oil, generally rape oil, under the same conditions, two oil-holders, one of which is filled with the standard oil and the other with the oil to be tested, being combined in one bath, and the oils passing out simultaneously through two tubes of the same shape. *A* is the bath, in which the two oil-holders *BB* are so placed as to be surrounded on all sides by the fluid in the bath. For this purpose the partition between *B* and *B* is open on top and below, so that the fluid can circulute in it from *a*. The two oil-holders *B B* are

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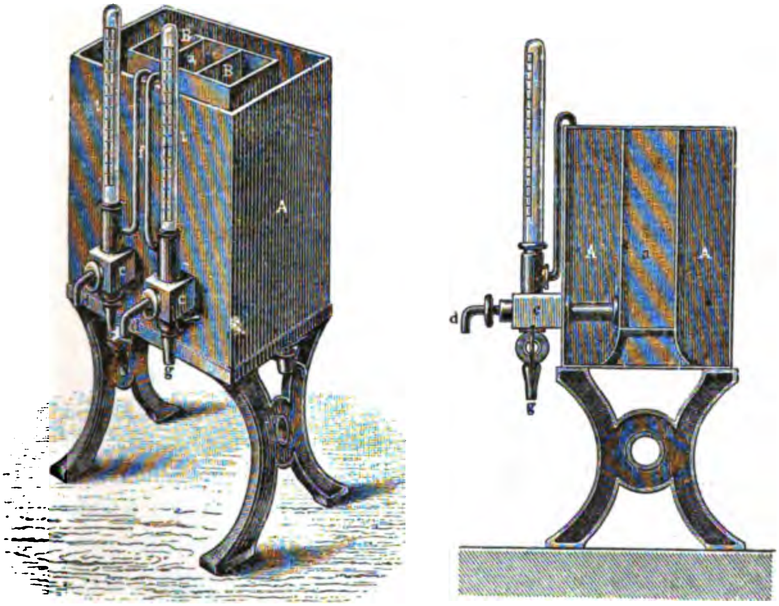
* λεπτός—fine, μέτρον—measure.

FIG. 12. FIG. 13.



LEPENAU'S LEPTOMETER.

connected below by means of pipes with *c c*, whence the oil, by three-way cocks, passes into a pipe in which outflow-orifices *d d* of different diameters, according to the consistency of the oil, are inserted; *t t* are thermometers, the bulbs of which dip into the oil passing through *c*, and *f* are rising pipes for the removal of air bubbles. Through *g* the oil can be directly discharged from *B B*, and by adjusting the three-way cock the oil can be run off through *d* or through *g;* or finally *B* can be shut off.

In making experiments, *a* is filled with a fluid for heating purposes. One of the vessels *B* is filled with standard oil and the other with the oil to be tested, and after heating to the desired temperature, both oils are allowed to run off simultaneously through the orifices *d d*. The comparative viscosity of the oil to be tested, as related to the standard oil, is then directly found from the volumes or weights of the oils run off.

At the ordinary temperature this apparatus gives very good results; it has, however, the defect that in consequence of the outflow-orifices not being in the heating bath, the oils in them will cool off several degrees, according to the surrounding temperature. The construction of the different outflow-orifices with perfectly uniform internal dimensions might also prove difficult; the outflow-orifices should at least not be bent as in the most recent constructions, they being difficult to clean and keep in order.

Redwood's Viscosimeter.—This apparatus is largely used in Great Britain, it having been adopted also by the Scotch Mineral Oil Association. It is described by Mr. C. R. Alder Wright* as follows: "The apparatus consists of an interior silvered copper cylinder about 1 7/8 inches in diameter and 3 1/2 inches deep, containing the oil to be examined. The bottom of this is furnished with an orifice, consisting of a hole bored through an agate plate, the top of which is excavated into a hemispherical cavity so that a small brass sphere attached to a rod and dropped in, forms a sufficiently tight valve. An outer jacket is provided with a closed copper tube projecting therefrom downwards at an angle of 45°, so that by heating this "tail" in a Bunsen or spirit lamp flame, the temperature of the liquid, (water, oil, melted paraffin wax, etc.) in the jacket can be raised as required. A revolving agitator to equalize temperature in the jacket is provided, with a thermometer attached, a second thermometer being supported in the oil by a clamp fixed on the cylinder. The whole rests on a tripod stand furnished with leveling screws. The constancy of initial level of oil inside the cylinder is assured by means of a gauge consisting of a small internal bracket with upturned point.

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*Animal and Vegetable Fixed Oils, etc. London, 1894.

"When an observation is to be made the bath is filled with water or heavy mineral oil, etc., and heated to the required temperature. The oil to be tested is also heated to this temperature and poured in until the level of the liquid just reaches the point of the gauge. A narrow-necked flask holding 50 cubic centimeters is placed beneath the jet immersed in a liquid at the same temperature as the oil. When all is ready the ball-valve is raised and a stop-watch started, and the number of seconds requisite to fill the 50 cubic centimeter flask noted, care being taken that the temperature does not fluctuate during the time and that the oil is perfectly free from suspended matter, such as dirt or globules of water."

Besides the determination of the velocity of the flow of an oil, there have recently been constructed viscosineters based upon different principles, of which J. C. Stahl's apparatus may be taken as a representative. It consists of a glass tube which can be closed on both ends by glass-stoppers. A short distance below these stoppers the tube is provided with marks, so that when the tube closed at one end is filled with the oil to be tested and the other glass stopper is inserted, there remains an air-bubble of a fixed size between the stopper and the mark. By holding the tube in a perpendicular position and then turning it 180° so that the glass stopper previously on top comes below, the viscosity can be measured by the time required by the air-bubble to ascend in the oil. The more viscous the oil is, the more slowly the bubble ascends.

Combustibility.—The quick or slow combustibility of oils is of great importance in judging their value as illuminants. Schuebler has made experiments in this respect with an ordinary lamp, and with a small lamp without wick. The latter lamp consists of a small glass tube about 0.106 inch in diameter floating in a small metal plate upon the surface of the oil, which is ignited at the mouth of the glass tube. The lamp with a wick consist of a metal tube of the same diameter containing sixteen fine cotton threads. The separate experiments were continued exactly an hour, and the quantity of oil consumed during this period determined.

To determine at the same time the quantity of heat developed during combustion, the lamp was brought into a vessel over which was placed, at a distance of 2¾ inches, a boiler, containing exactly 600 parts by weight of water. After one hour the water was weighed and the evaporated quantity calculated.

The results of the experiments are given in the following table:

Names of the Oils.	Combustibility of Oils.			
	In a lamp without wick.		In a lamp with wick.	
	Quantity in one hour.			
	Oil consumed.	Water evaporated.	Oil consumed.	Water evaporated.
	Parts by weight.	Parts by weight.	Parts by weight.	Parts by weight.
Olive oil	53.1	150	62.0	230
Sunflower-seed oil	41.0	133	51.8	185
German sesamé oil	36.0	105	34.0	101
Pumpkin-seed oil	34.2	101	43.7	135
Weld-seed oil	34.1	100	44.0	148
Almond oil	33.5	99	52.8	183
Hazel-nut oil	32.5	97	53.4	190
Spindle-tree oil	32.1	95	61.0	225
Hemp oil	31.4	94	46.0	155
Plum-kernel oil	30.8	90	68.0	260
Beech-nut oil	30.5	87	50.0	170
Pinaster-seed oil	30.0	84	49.8	164
White mustard-seed oil	29.3	82	29.8	78
Belladonna oil	29.0	82	38.2	110
Spring rape-seed oil	27.5	70	33.0	94
Colza oil	26.9	68	42.7	140
Pine oil.	26.5	65	47.3	160
Cress-seed oil	24.4	58	42.0	137
Linseed oil	24.2	57	38.7	121
Nut oil	23.4	55	45.0	150
Castor oil	23.3	46	47.0	168
Radish-seed oil	20.0	42	43.0	138
Poppy-seed oil	19.8	41	31.0	80
Grape-seed oil	18.4	33	37.0	120
Tobacco-seed oil	17.7	36	33.2	95
Fall rape-seed oil*	12.0	22	40.0	133
Black mustard-seed oil	extinguishes in a few minutes.		25.0	68
Hesperis oil			24.0	59

* Not refined.

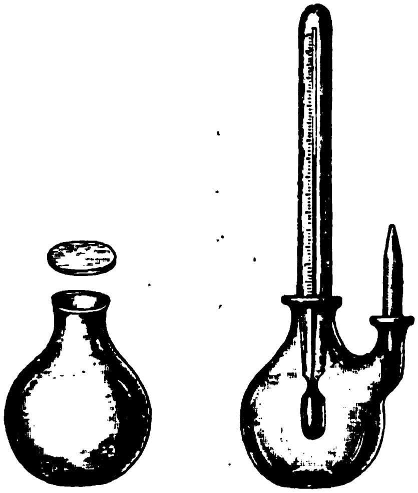
Determination of the specific gravity.—By specific gravity is understood the weight of a liquid or solid body as compared with that of an equal volume of pure water. If, therefore, the weight of 100 cubic centimetres of oil = 95.32 grammes, and that of 100 cubic centimetres of water = 100.00 grammes, the specific gravity of the oil =

$$\frac{95.32}{100.00} = 0.9532$$

The specific gravity of fatty substances can be accurately determined by different methods, of which we mention the following:—

1. By the *picnometer*, or *specfiic gravity bottle*, Fig. 14, a small, pear-shaped glass vessel provided with a glass stopper. It is filled with water and weighed. It is then emptied, thoroughly dried, and filled with the oil to be examined, and again weighed. The volumes of water and oil used being equal, it is only necessary to divide the weight of the oil by that of the water to obtain the specfic gravity of the oil. For example:—

FIG. 14.



PICNOMETER.

Weight of the empty picnometer,		11.532 grams.
" " " " filled with distilled water,		24.832 "
	24.832	
Subtract	11.532	
	13.300	
Weight of the picnometer, with oil,		23 668 grams.
" " " " without oil,		11.532 "
		12.136 "

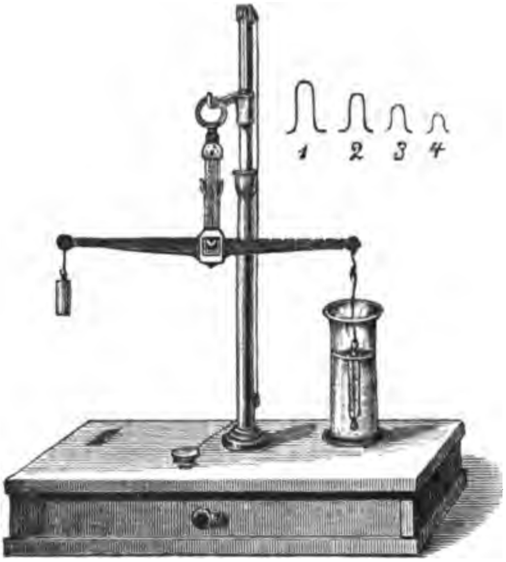
We have now the proportion:

$$13.300 : 12.136 = 1 \text{ (specific gravity of water)} : X$$

consequently $X = \frac{12.136.1}{13.300} = 0.91250$ = spec. grav. of the oil.

2. *Mohr's specific-gravity balance.*—The construction of this

FIG. 15.

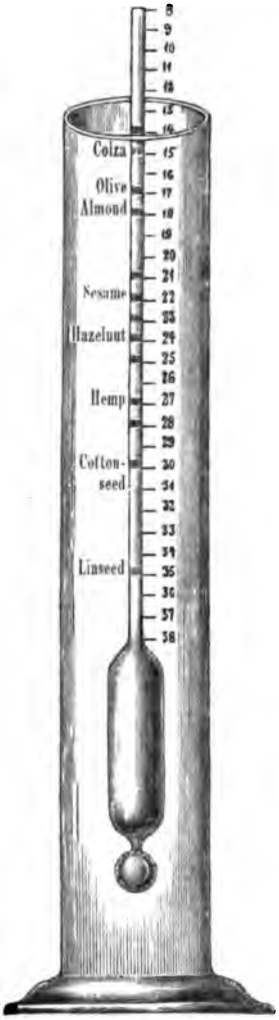


MOHR'S BALANCE.

instrument, which permits very exact and rapid determinations of specific gravity, depends upon the principle, that the loss of weight which one and the same body suffers in different liquids is proportioned to the density of the latter. One arm of the balance (Fig. 15), is divided into ten equal parts, and upon it is suspended by means of a fine platinum wire a glass vessel embracing a thermometer, which is exactly balanced by a weight affixed to the other arm. The equilibrium caused by a loss of weight of the glass vessel when immersed in water of 4° C. (39.2° F.) is restored by appending an adjusted weight. There are four weights (riders), No. 2 being equal to $\frac{1}{10}$, No. 3 to $\frac{1}{100}$, and No. 4 to $\frac{1}{1000}$ of No. 1. If, now, after immersing the glass vessel in an oil, the riders are placed in the division marks, the first indicates the tenths, the second the hundredths, the third the thousandths, and so on.

3. In commerce, especially constructed instruments called elaïometers, oleometers, or oil balances are used. Such instrument is a delicate aerometer or hydrometer so weighted and graduated as to adapt itself to the densities of the principal fixed oils.

FIG. 16.



LEFEBVRE'S OLEOMETER.

Lefebvre's oleometer, Fig. 16, which is much used, has the form of an ordinary oleometer, except that the bulb is larger and the tube or stem very long. The latter is provided with a scale upon which the principal oils occurring in commerce are indicated. As it would be scarcely possible to place four figures alongside each other upon the scale, the first and last decimals are omitted. On the place for rape oil, for instance, stands the figure 15, which must be read 0.9150 specific gravity. On the left of the scale, opposite to the figures of the specific gravity, are the names of the various oils. To facilitate the reading, the oils are indicated by a color closely resembling that acquired by them by the test with sulphuric acid.

The standard temperature of the oleometer is 15 C. (59° F.), and the experiments must therefore be made at this temperature.

If oils are tested at a different temperature, the difference in the specific gravity is 0.001, more or less, for each 1.5° C. above or below the standard temperature; therefore, 0.002 for every 3° C., 0.004 for every 6° C., and so on. At 18° C. $\frac{2}{1000}$ must consequently be added to the specific gravity, and at 12° C. $\frac{2}{1000}$ subtracted.

In Germany *Fischer's oil balance* and *Brix's hydrometer* are in general use and employed by all customs offices. Fischer added to his oil balance printed instructions exhibiting the degrees which pure oil should show with his balance. However, he never made public the principle of construction, and as the mechanics making the balance worked only by sample, the principle of construction being unknown to them, it will be readily understood that in commerce the balances yield greatly varying results.

Fischer in his instructions says:

"This balance shows the specific gravity of the fat oils in degrees. If the temperature of the oils has been brought to *o* according to the thermometer, a good quality of

Rape oil shows	38–39	degrees.
Olive "	38	"
Camelina oil shows	33–34	"
Poppy "	32	"
Linseed "	29–30	"
Train "	33	"

"Mixtures of various oils give different results, for instance, equal parts of rape oil and camelina oil give an oil of 36 to 37 degrees. By artificial purification the above mentioned oils become specifically lighter and show one degree less."

Gerlach has discovered the principle of Fischer's oil balance by comparing Fischer's degrees and the specific gravities at 12.5° Rèaumur (60.1°F.), and found that Fischer's degrees correspond with the specific gravities of Brix's hydrometer-degrees. The latter are based upon the formula:

$$X=\frac{400}{400+n}$$

in which *X* means the specific gravity and *n* the number of degrees read off on the instrument.

As regards the oils, Fischer's or Brix's degrees correspond to the following specific gravities:

Degrees.	Specific gravity.	Degrees.	Specific gravity.	Degrees.	Specific gravity.
0	1.000	17	0.9593	34	0.9217
1	0.9975	18	0.9569	35	0.9195
2	0.9950	19	0.9547	36	0.9174
3	0.9926	20	0.9524	37	0.9153
4	0.9901	21	0.9501	38	0.9132
5	0.9877	22	0.9479	39	0.9112
6	0.9852	23	0.9456	40	0.9091
7	0.9828	24	0.9434	41	0.9070
8	0.9804	25	0.9412	42	0.9050
9	0.9780	26	0.9390	43	0.9029
10	0.9756	27	0.9368	44	0.9009
11	0.9732	28	0.9346	45	0.8989
12	0.9709	29	0.9324	46	0.8969
13	0.9685	30	0.9302	47	0.8949
14	0.9662	31	0.9281	48	0.8929
15	0.9639	32	0.9259	49	0.8909
16	0.9615	33	0.9238	50	0.8889

Other hydrometers are those of Gobley, Pinchon, Donny, etc.

It has previously been stated that the percentage yield of fat of seeds, fruits, etc., is dependent on the manner of cultivation, condition of the soil, manure, weather, degree of ripeness, etc. The conditions are also of influence upon the variations in the specific gravity of one and the same oil, and, according to the age, mode of preparation, etc., of the oil these variations may be as great as the differences between one oil and another which serves as an adulterant.

The want of agreement in the determinations of the specific gravity in this respect is plainly illustrated by the following table:

	Scharling.	Lefebvre.	Schuebler.
Rape oil	0.9228	0.9154	0.9128
Linseed oil	0.9383	0.9350	0.9347
Poppy oil (old)	0.9630	0.9253	0.9243
Train oil	according to kinds 0.9175–0.9317	0.9240	0.9231
Olive oil	—	0.9180	0.9176

While in Germany, Austria and England, densimeters are being more and more introduced, in America and Russia, Baumé's scale is almost exclusively used, and in Italy Lefebvre's and Gobley's oleometers, Lefebvre's being also employed in France besides Gay-Lussac's volumeter. In the Hamburg train oil commerce even Stoppani's oil balance is still used.

The following table serves for a comparison of the various scales:

COMPARISON OF HYDROMETERS.

Hydrometer of	Fluids heavier than water.	Fluids lighter than water.
Baumé at 17.5^C C.	$\frac{146.78}{146.78 - n^*} = S$	$\frac{146.78}{136.78 + n} = S$
Baumé, rational, at 15° C.	$\frac{144.3}{144.3 - n} = S$	$\frac{144.3}{134.3 + n} = S$
Brix, official, at 15.625° C. Fischer, E. G. Greiner	$\frac{400}{400 - n} = S$	$\frac{400}{400 + n} = S$
Gay-Lussac at 4° C.	$\frac{100}{100 - n} = S$	$\frac{100}{100 + n} = S$
Stoppani at 15.625° C.	$\frac{160}{160 - n} = S$	$\frac{160}{160 + n} = S$
Balling at 17.5° C.	$\frac{200}{200 - n} = S$	$\frac{200}{200 + n} = S$
Beck at 12.5° C.	$\frac{170}{170 - n} = S$	$\frac{170}{170 + n} = S$
Cartier at 12.5° C.	$\frac{136.8}{126.1 - n} = S$	$\frac{136.8}{126.1 + n} = S$

* n = degree. S = specific gravity.

Lunge and Hurter* regard the series of values got by means of the formula $S = \frac{144.3}{144.3 - n}$ as the only "rational" one of the various Baumè scales in use; taking the formula at 15° C. (59° F.), the specific gravity of water at 15° C. = 0 °B. whilst 66° B. represents specific gravity $\frac{144.3}{144.3 - 66} = 1.8426$. The following table exhibits the relationship between the values of "rational" Baumé degrees, Twaddell degrees, and true specific gravity:

Baumé.	Twaddell.	Specific gravity.	Baumé.	Twaddell.	Specific gravity.
0	0	1.000	36.0	66.4	1.332
0.7	1.0	1.095	38.0	71.4	1.357
1.0	1.4	1.007	40.0	76.6	1.383
1.4	2.0	1.010	42.0	82.0	1.410
2.0	2.8	1.014	44.0	87.6	1.438
2.7	4.0	1.020	46.0	93.6	1.468
4.0	5.8	1.029	48.0	99.6	1.498
5.0	7.4	1.037	50.0	106.0	1.530
6.7	10.0	1.050	52.0	112.6	1.563
8.0	12.0	1.060	54.0	119.4	1.597
10.0	15.0	1.075	56.0	127.0	1.635
14.0	21.6	1.108	58.0	134.2	1.671
16.0	25.0	1.125	60.0	142.0	1.710
18.8	30.0	1.150	61.0	146.4	1.732
20.0	32.4	1.162	62.0	150.6	1.753
23.0	38.0	1.190	63.0	155.0	1.775
25.0	42.0	1.210	64.0	159.0	1.795
27.0	46.2	1.231	65.0	164.0	1.820
30.0	52.6	1.263	66.0	168.4	1.842
33.0	59.4	1.297	67.0	173.0	1.865

For the determination of the specific gravity of more solid fats and waxes, Dr. Hager gives the following method:

The fat is melted and carefully dropped into alcohol or diluted alcohol, in which it is again allowed to solidify. The solidified drops are then transferred to a second vessel containing a liquid, the density of which is increased or decreased by the addition of alcohol, water, or glycerin until the fat shows a tendency to float, but does not rise or sink at once. The specific gravity of the liquid is then that of the fat. However, since dropping of the melted mass into alcohol or diluted alcohol at a medium temperature produces variations according as the fat is heated and later on cooled off, this method has been modified as follows:

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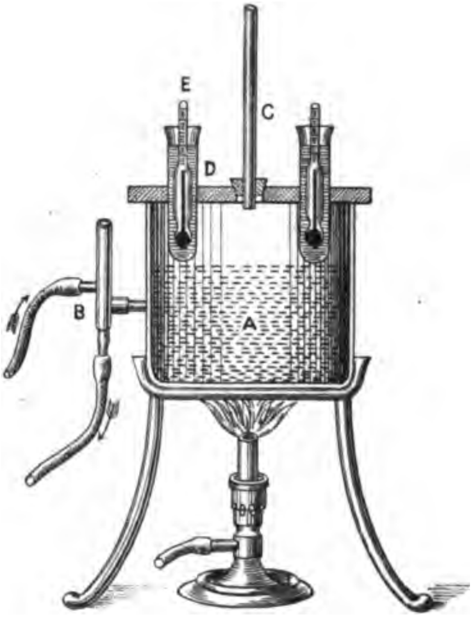
* Alkali-Maker's Pocket-Book.

The fat is carefully melted to a semi-fluid mass and allowed to fall drop by drop from a glass rod into a beaker filled half with water standing in a freezing mixture. The separate drops remain in the cooled water until the later has acquired the temperature requisite for the determination of the specific gravity.

FIG. 17.



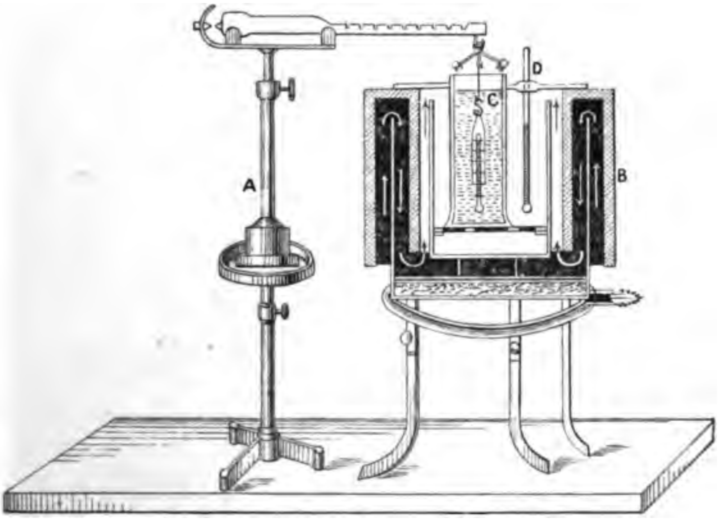
KOENIG'S APPARATUS.

The small globules of fat are then dried with blotting paper when they are ready for the floating test described above.

In determining the specific gravity and in judging the quality of oils dependent on fluctuations of the specific gravity, due consideration has to be given to the temperature at which the determination has been made, since oils possess a greater capacity for expanding at a higher temperature than most other fluids.

Determination of the specific gravity at a higher temperature.—Lefèbvre assumed for all oils the same proportion of expansion at the same degree of temperature. Contrary to this Scharling proved that, notwithstanding equality or dissimilarity of the specific gravity at 59°F., fats and oils at the same high degrees of temperature show different expansion-coefficients; hence an oil or fat specifically heavier at an ordinary temperature than another oil or fat may be specifically lighter at 212° F., for instance, butter, specific gravity at 59°F. = 0.938, at 212° F. = 0.860; Lard, specific gravity at 59° F. = 0.938, at 212° F. = 0.868.

FIG. 18.



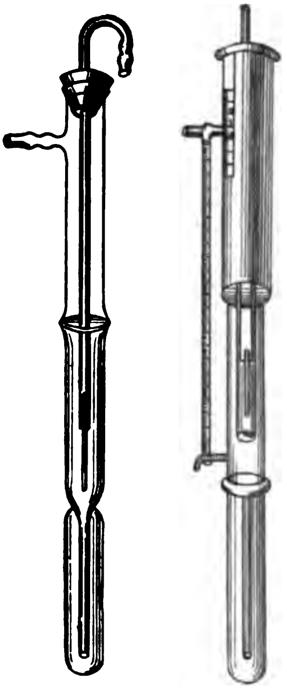
BELL'S APPLICATION OF WESTPHAL'S BALANCE.

The determination of the specific gravity at higher temperatures has recently been applied by A. Meyer, E. Koenig, Leune, and others, to the purpose of identifying and judging oils, etc. Various apparatuses for testing the oils have been constructed, a few of them being shown in Figs. 17 to 21.

The mode of construction is indicated by the illustrations. Fig. 17 shows Koenig's apparatus, in which *A B* is a water-bath with constant level, *C* a thermometer, *D* tube containing the oil, and *E* a hydrometer. The water-bath is heated by a gas flame.

Bell's application of Westphal's balance is shown in Fig. 18. The vessel *C*, containing the oil, etc., to be examined, is heated by a hot air-bath *B*, the ascending hot gases from a ring burner being made to circulate as indicated by the arrows. The temperature of the inner hot space is shown by the thermometer *D*, and should not differ much from that of the oil itself, as indicated by a thermometer immersed therein (in the illustration this is enclosed inside the plummet). A thermostat or heat regulator where the gas supply is automatically regulated should be employed in addition. Fig. 19 represents Bunsen's thermostats. The principle of these regulators consists in that the air in the lower part when expanded by heat regulates, and eventually closes by means of mercury, the aperture through which the illuminating gas serving for heating is supplied. The gas flows from the principal tube through the movable vertical supply-tube closed by mercury and through the lateral tube to the burner.

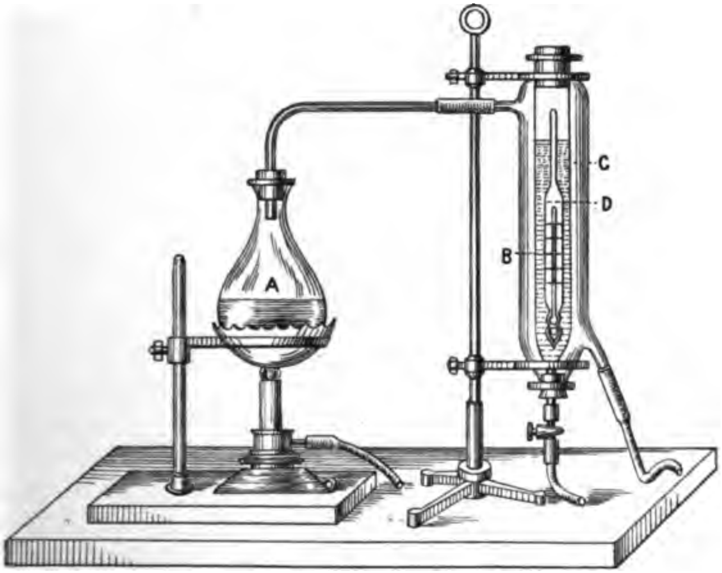
FIG. 19.



BUNSEN'S THERMOSTATS.

Fig. 20 represents Ambühl's arrangement. A boiling flask *A* with a flat bottom serves for the generation of steam. A large test-glass *B*, for the reception of the oil passes through a perforated cork, but does not fit firmly in the latter, the cork being provided with four triangular cuts, so that the steam from the flask must wash the top of the test-tube and heat it. A thermometer *C* passes through a second perforation in the cork. The plummets *D* are provided with scales from 0.950 to 0.900 and 0.900 to 0.840, and a thermometer enclosed inside. In using the apparatus the degrees of temperature can be easily read off on the thermometer *C* and the plummet *D*. The oil-vessel *B* should not dip into the water, and it is recommended to add a small quantity of common salt to the latter. The generation of steam and the heating of the oil are very rapidly effected. To obtain exactly a temperature of 212° F., it is advisable to place a cyclinder of pasteboard covered inside and outside with flannel upon the flask. The cylinder rests upon the lower conical enlargement of the flask, and can be readily removed and replaced. The hydrometers having been adjusted

FIG. 20.

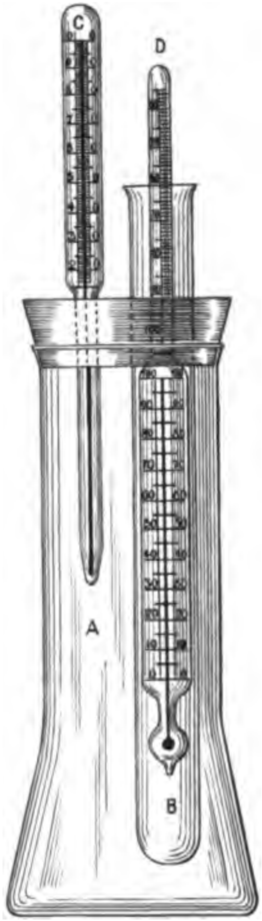


AMBÜHL'S ARRANGEMENT.
A, flask; *B*, glass-jacket; *C*, oil vessel; *D*, hydrometer.

to 59° F., the comparative values have to be referred to this temperature.

The most simple arrangement is shown in Fig. 21, in which

FIG. 21.



MOST SIMPLE ARRANGEMENT.
A, boiling flask; *B*, oil-vessel; *C*, thermometer; *D*, hydrometer.

A represents the boiling flask, *B* the oil-vessel, *C* the thermometer, and *D* the hydrometer.

Specific Gravity of some Oils and Fats at 212° F.

Names of the Oils, etc.	Specific gravity at 59° F.	Specific gravity at 212° F.
Bees' wax	0.960	0.822
Butter	0.930	0.868
Cacao butter	0.950	0.857
Castor oil	0.963	0.910
Cocoanut oil	0.925	0.863
Cotton-seed oil	0.926	0.871
Hemp-seed oil	0.927	0.872
Japanese wax	0.972	0.870
Lard	0.938	0.860
Linseed oil	0.936	0.880
Mineral oil	0.891 0.930	0.842 0.850
Olive oil (Nice)	0.917	0.869
Palm oil	0.945	0.857
Palm-kernel oil	0.952	0.866
Peanut oil	0.920	0.864
Poppy oil	—	0.872
Rosin oil	0.925	0.910
Sesamé	0.923	0.871
Spermaceti	0.992	0.809
Suet (ox tallow)	0.953	0.859
Tallow (sheep)	0.935	0.860
Turnip seed	0.913	0.862

Freezing or solidifying point. By this is understood the *point at which, by the withdrawal of heat, oils, fluid or semi-fluid at an ordinary temperature, solidify.* It is determined in a test-tube 0.31 to 0.35 inch in diameter, filled ⅓ with oil, into which dips a thermometer as shown in Fig. 22. The cork which supports the thermometer does not fit closely on one side so that the ordinary atmospheric pressure prevails in the test-tube. The scale of the thermometer—from —30°C. to 20°C. —is above the cork, so that the degrees can be conveniently read off. The test-tube is slowly moved to and fro in a freezing mixture, the oil carefully observed and the freezing point noted. With the same arrangement it may also be accurately determined at which temperature the oil becomes again fluid; thus poppy oil freezes only at —20°C. (—4°F.) and remains thus up to—2°C. (28.4°F.), but above this temperature the oil becomes rapidly fluid.

Suitable freezing mixtures are as follows:

For —20°C. (—4°F.): Ammonium chloride 5 parts, saltpetre 5, Glauber's salt 8, water 16.

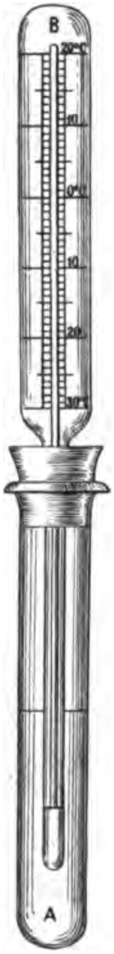
For —25° C. (—13°F.): Common salt 1 part, melted ice or snow 2.

For —30C. (—22°F.): Common salt 2 parts, ammonium chloride 1, ice 5.

For —35°C. (—31°F.): Common salt 5 parts, ammonium chloride 1, saltpetre 1, ice 5.

As a rule, it suffices to wrap cotton round the lower part of the test-tube and moisten it with ether or carbon disulphide, etc. By their evaporation cold is produced and the solidifying point or the various stages of solidifying can be readily read off on the thermometer.

FIG. 22.



ARRANGEMENT FOR DETERMINING THE FREEZING POINT.

A, test-tube; *B*, thermometer.

Fusing point. This is *the temperature at which a softer or more solid body, such as lard, tallow, wax, is, by the conveyance of heat, converted into a fluid state.* For the determination of the fusing points of fats, various methods have been proposed which differ essentially in that either the temperature at which the fats commence to show signs of melting is taken as the fusing point, or that at which they run down as a clear, transparent fluid, the former being called the *initial fusing or softening point* and the latter the *ultimate fusing point or temperature of complete fusion.*

In all preparations for determining the fusing point, the fat should be used in a semi-fluid state, *i. e.*, to avoid over-fusing, the fat is placed in a dish and carefully melted, stirring slowly until it is semi-fluid.

According to Buis, very thin-walled glass-tubes of 0.11 inch internal diameter and 1.18 inches long, drawn out perfectly cylindrically and smooth inside, are filled by suction with semi-fluid fat. These tubes, as in all succeeding determinations, are laid aside for 12 to 48 hours, according to the season of the year, in a cool place or upon ice, until the fat is thoroughly solidified. This has to be carefully attended to, because soft fats especially, very slowly acquire their natural solidity.

FIG. 23.

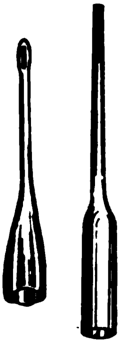
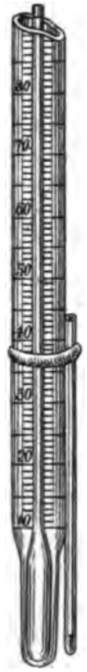
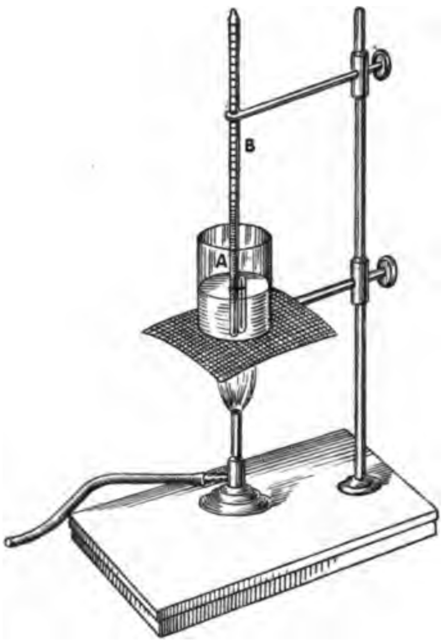


FIG. 24.



25.



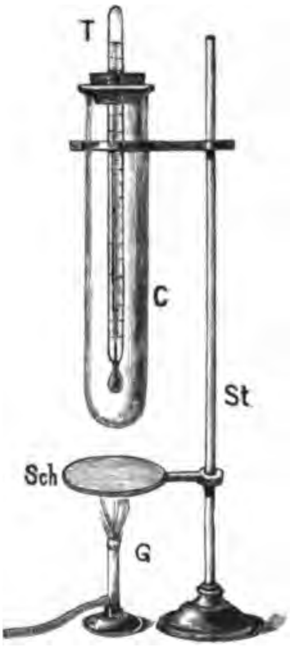
ARRANGEMENT FOR DETERMINING THE FUSING POINT.

A, beaker; *B*, thermometer with tube.

The tubes thus prepared are placed in a beaker filled with water in which is fixed an accurate thermometer, and the water very slowly heated. At the moment the fat is forced upward in the tube the temperature is read off. Since the fat is forced upwards very suddenly, the experiments have to be repeated and the mean of the results is taken as the fusing point.

Such tubes, closed below or of the form shown in Fig. 23, are also employed as follows: The tube is bound by wire, string or an india-rubber ring to the stem of a thermometer, Fig. 24, so that the centre of the bulb is about level with the substance. The whole is then placed in a beaker filled with water, Fig. 25, (or for higher temperatures melted paraffin wax) which is very slowly raised in temperature by means of a small flame underneath.

FIG. 26.



According to Pohl, a coat of fat is directly applied to the bulb of a thermometer, by dipping the latter into the semi-fluid fat, and immediately withdrawing it to prevent the mercury from becoming heated. After repeating the operation several times, the thermometer is laid aside to allow the coat of fat to congeal. It is then placed in a beaker filled with cold water, and heat is gradually applied until the fat becomes transparent or melts off. Or the thermometer, coated with fat, is placed in a wide glass tube, and secured by a cork. The tube is then clamped to a stand (Fig. 26). About three-quarters to one inch below the bottom of the tube is a piece of tin to protect it from the direct effect of the gas flame. In this manner the degree at which the fat becomes transparent can be determined, and also that at which it melts off. In the illustration, *T* is the thermometer, *C*, the glass tube, *St*, the stand, and *Sch*, the protecting tin.

The difference between the appearance of transparency and melting off is, according to the variety of fat, up to 1.5° C.

(2.7° F.), the same differences appearing also in observations with the first two methods.

Lard, suet (ox tallow), and sheep tallow, become transparent only several degrees above their fusing points, for instance, lard at 47° C. (116.6° F.), while Japanese wax shows a contrary behavior, it becoming transparent at 41° C. (105.8° F.) 10° C. (50° F.) below its fusing point.

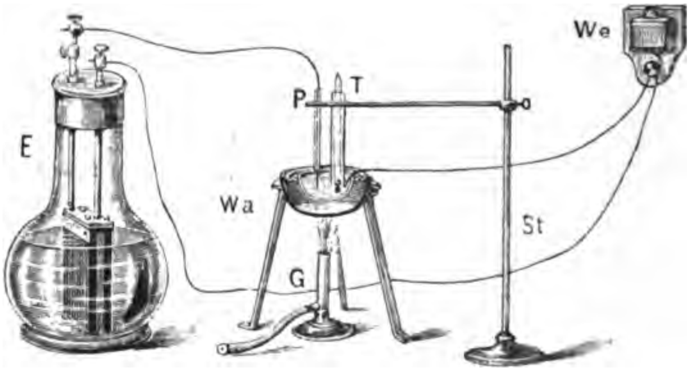
This peculiar behavior of fats explains the different results regarding the fusing points obtained by different observers, as shown in the annexed table, and how necessary it is to establish a uniform determination.

VARIOUS STATEMENTS REGARDING THE FUSING POINTS.

Name of Observer.	Lard. Degrees F.	Tallow. Degrees F.	Suet. Degrees F.	Wax. Degrees F.
Berzelius	84	—	—	112
Chateau	86 to 88	—	98.5	113
Schubarth	82.5	—	—	113
Perutz	80.5	—	—	—
Wimmel	107 to 107.5	109.5	117	112
Bolley	—	98.6 to 104	—	—
Thomson	—	100.5	—	127.5
Muspratt	—	—	100.5 to 106	—
Person	—	—	—	109
Pouillet	—	—	—	120
Lepage	—	115	—	—
Dulk	—	—	—	122

A method first proposed by Julius Loewe, gives always the same results, and is, therefore, well adapted for the exact determination of the fusing points of many substances. It depends upon the fact that an electric current of low power interrupted by a layer of fat can set in motion an alarm as soon as the fatty substance ceases to prevent the passage of the current. The apparatus may be constructed as follows: A porcelain capsule (Fig. 27), about two inches deep and three and a half inches wide, filled with mercury, is set into a small copper water-bath, *Wa*. By means of a clamp attached to the retort-stand *St*, an accurate thermometer, *T*, inclosed within a glass tube (to avoid changes of temperature by the surrounding air), is immersed in the mercury. By means of the same retort-stand a rather thick platinum wire, *P*, is firmly fixed so as to dip a short distance into the mercury. One end of this wire is bent into an eye, which is connected with the copper wire of the zinc pole of the battery. The platinum wire itself is inserted in a glass tube, and secured with sealing-wax for the purpose of keeping it straight and rigid. For the continuation of the current another thinner platinum wire dips into the mercury and connects with a copper wire leading to the alarm. The other pole of the battery is in direct connection with the latter. If the apparatus is properly constructed, on closing the current the alarm should instantly sound. Having made this preliminary trial the stout platinum wire *P* is disconnected, its lower end, which had dipped into the mercury, strongly ignited and allowed to cool under mercury, after which it is quickly plunged into the almost melted fat-substance, the fusing point of which is to be determined.

FIG. 27.

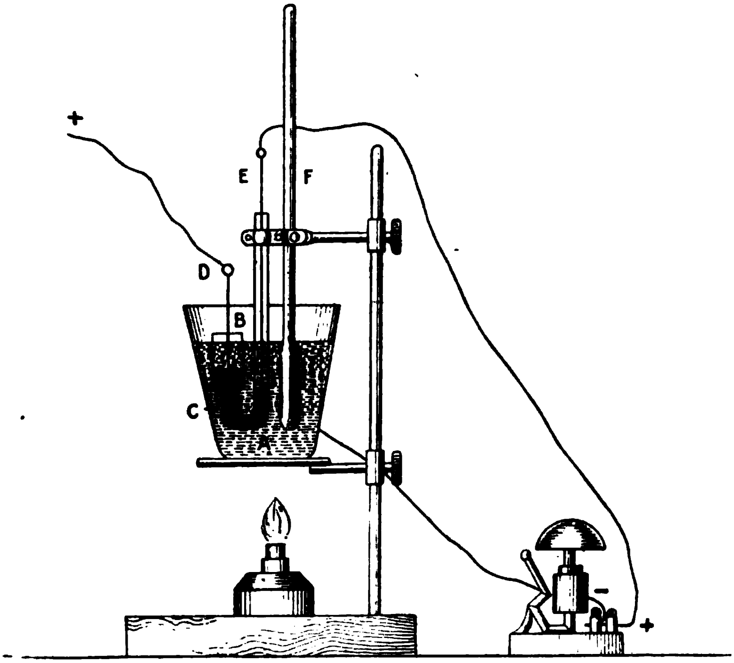


APPARATUS FOR THE DETERMINING OF MELTING POINTS.

The coating need not be thicker than a few millimetres in order to interrupt the current. On now re-connecting the platinum wire with the apparatus as before, the current cannot pass, and the alarm will not sound. But if the water-bath, and with it the mercury, be gradually heated, a point will be reached at which the coating around the end of the wire melts, and by re-establishment of the current the alarm will be sounded. At this moment, which indicates the actual fusing point of the substance, the temperature is read off.

J. Loewe's method, slightly modified, has been introduced in the Paris Municipal Laboratory by F. Jean. The apparatus

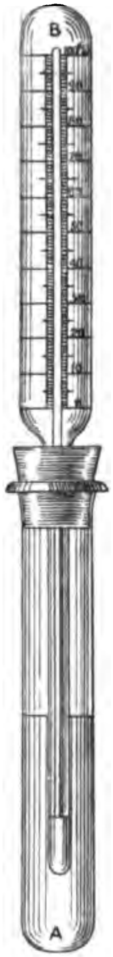
FIG. 28.



F. JEAN'S ELECTRIC APPARATUS FOR DETERMINING THE FUSING POINT.
A, water-bath; *B*, U-shaped tube; *C*, mercury; *D*, *E*, platinum wires; *F*, thermometer.

employed is shown in Fig. 28, and may be briefly described as follows: The fat in a fluid state is placed in the bend of the U-shaped tube *B*, with a platinum wire in each limb. When the fat has become solid a definite quantity of mercury, *C*, is poured into the wider limb, which runs down and makes contact when fusion occurs, and a bell rings, giving the alarm for reading off the temperature. The U-shaped tube *B* is placed in a water-bath, together with a thermometer *F*, and is heated by a gas or spirit flame.

FIG. 29.



INSTRUMENT FOR THE DETERMINATION OF THE FUSING AND SOLIDIFYING POINTS.

A, test-tube; *B*, thermometer.

A method for determining the fusing point, much used in ceresin factories, has been introduced by Kletzinsky. A glass rod is bent in a sharp angle so that it can be up to the centre suspended in a beaker. A piece of ceresin, Japanese wax, etc., is melted on in the sharp angle, the beaker filled so far as requisite with water, and the water heated. Previously a thermometer fixed to a stand is inserted in the water directly up to the angle where the ceresin or wax is. When the water is heated so far that the ceresin melts off, the temperature is read off, and this is taken as the fusing point.

The fusing point may also be conveniently determined with very accurate results in an analogous, but reverse manner as the freezing point. A similar arrangement, Fig. 29, is used, the only difference being that the thermometer is graduated from 0° to 100° C. The instrument may also be used for the determination of the solidifying point and the evolution of heat taking place thereby.

For use the fat, etc., in a semi-fluid state is brought into the test-tube, and after placing the thermometer in position, is gradually cooled in the manner described on p. 71. Water in a beaker is then gradually heated, the test-tube slowly moved in it to and fro, and the initial and ultimate points of fusion determined.

Solidifying point. This is the ***temperature at which more or less solid fats, etc., after fusing, pass again into the solid state at an ordinary temperature.***

The determination of the solidifying point is of greater importance than that of the fusing point, since the fats, in passing from a fluid into a solid state, exhibit a very peculiar behavior.

It may be accepted as a general rule that the fusing and solidifying points of a substance are identical, which, however, is not the case with fats, paraffins, etc.

During the solidification of the fats an increase of temperature always takes place, a fact already observed by Chevreul.

All actual fats, so-called glycerides, exhibit the remarkable though abnormal behavior, that under ordinary circumstances they solidify after fusing at a temperature more or less below the fusing point. This property distinguishes them from other fat-like substances which are not paraffins or glycerides, but other varieties of ethers; for instance, bees' wax and spermaceti, which solidify immediately below the fusing point.

Another peculiarity of fats is that when remelted after solidifying they do not solidify at the same temperature as before, and that, when overchilled, they remain perfectly fluid even several degrees below their true solidifying point, but then suddenly solidify under liberation of heat. Water shows a similar phenomenon of overchilling; by frost and complete quiet it can cool down to several degrees below the freezing point without freezing.

If fat is heated to above its fusing point and then allowed to cool, its solidifying point lies close to the fusing point. In this case there is frequently no increase of temperature.

All these peculiarities render observations as to the solidifying points extremely inaccurate, and are the cause why authors differ very much in regard to them.

For the determination of the solidifying points the small glass tubes closed on one end, used for determining the fusing point, can be employed by combining the determination of the fusing point with that of the solidifying point, *i. e.*, the water is allowed to cool and the degree noted at which the fat becomes again opaque. To observe, at the same time, the rise in temperature during solidification, it is only necessary to introduce a thermometer into the carefully melted fat and observe the variations of temperature, taking into consideration that the quicker a fat congeals the greater the consequent rise in temperature, and, *vice versa*, the slower the process of congealing the less perceptible the rise in the temperature will be.

In using the previously described instrument, Fig. 29, it is, therefore, best to note the solidifying point immediately after determining the fusing point. For this purpose the test-tube is taken from the beaker and the solidifying point established while slowly moving the tube to and fro in the air.

Boiling point.—Fats and oils have no fixed boiling points. At the apparent boiling point decomposition commences, with evolution of various gases and noxious vapors, which readily ignite and burn with a bright flame. Generally speaking, fat oils boil at 280° to 300° C. (536° to 572° F.), and solid fats at 300° to 325° C. (572° to 617° F.)

During the progressive changes in the temperature an actual boiling, *i. e.*, an ebullition as in water, is not observed, but according to the degree of heating only a more or less strong spurting takes place, which at the same time indicates decomposition.

The decomposition of fats and oils is considerably influenced by more rapid or more careful heating.

From the fact that fats and fat oils have no permanent boiling points, but undergo decomposition, it follows that they are not volatile; they can, however, be distilled in a vacuum without suffering decomposition.

Expansion.—With an increase of 1° C. (1.8° F.) the expansion of 1000 volumes amounts in olive oil to 0.83 volume, in rape oil to 0.89, and in train oil to 1. It must, however, be remarked that the freezing of oils is also connected with an increase in volume, *i. e.*, expansion, which may be of such a degree as to cause the barrel to burst.

Thus 1000 quarts of olive oil measured in winter at 32°F. and in summer at 68° F. increase to 1016.6 quarts, the same quantity of rape oil to 1017.8 quarts, and the same quantity of train oil to 1020 quarts.

When the sale of oil is effected by measure and not by weight, the property of expansion has to be duly considered.

The influence of the temperature upon the specific gravity is shown by the following determinations of Saussure:—

Names of Oils.	At 12° C. (53.6° F.)	At 25° C. (77° F.)	At 50° C. (122° F.)	At 90° C. (194° F.)
Nut oil	0.928	0.919	—	0.871
Almond oil	0.920	—	—	0.863
Linseed oil	0.939	0.930	0.921	0.881
Castor oil	0.970	0.957	—	0.908
Olive oil	0.919	0.911	0.893	0.862

Drying of oils (*see also linseed oil*). By exposure to the air the oils absorb oxygen and remain either fluid—become rancid—or *dry*, whereby a disagreeable odor is evolved. During the process of becoming rancid a decomposition into fatty acids and glycerin takes place; but in drying, a process of combustion, the oils absorb oxygen while at the same time yielding carbonic acid. The property of drying varies according to the composition of the oils, Chinese wood oil or tung oil drying in the shortest time, next linseed oil, etc. Castor oil stands on the line between drying and non-drying oils.

To test oils as to their drying capacity, coat one side of a glass plate with a film of oil and let it stand in a warm place.

According to Livache the absorption of oxygen is much quickened by the addition of precipitated metallic lead.*

The general physical properties of fats and oils are only of relative value. An oil obtained from one and the same fruit may possess entirely different properties according to whether it has been expressed or extracted.

---

*Precipitated from lead acetate solution and rapidly washed in succession with water, alcohol and ether, and finally dried in vacuo.

Oil expressed from the same kind of seed may also possess different physical properties, as shown, for instance, by the following differences in the specific gravities:

	First pressure. Specific gravity at 59° F.	Second pressure. Specific gravity at 59° F.
Freshly-expressed poppy oil..............	0.9258	0.9285
" sesamé oil...............	0.9200	0.9250

On the other hand, an Indian peanut oil of the first and second pressures showed incidentally the same specific gravity = 0.9185 at 59° F.

The physical properties of oils are further influenced by the mode of expression, whether cold or warm, at what pressure, whether filtered cold or warm, or clarified by standing, etc.

For the reasons above mentioned the fusing points, etc., of fats are also subject to variations, most animal fats exhibiting such variations according to the season of the year when obtained, mode of feeding the animals, etc.

General Physical Properties of the Vegetable Fats, Oils and Waxes.

Non-drying oils are indicated by an asterisk (*); Drying oils by a dagger (†).

Name of the Oil, Fat or Tallow.	Color.	Odor.	Taste.	Specific Gravity at 15° C.	Consistency at 15° C. like	Freezing Point ° C.	Fusing Point ° C.	Solidifying Point ° C.
* Almond { sweet	slightly pale yellow or straw color,	odorless.	agreeably mild,	0.91844 { 0.9190	olive oil,	—20–21	—	—
bitter				0.91857			—	—
* Anda.	pale yellow,	odorless,	tasteless,	0.927	almond oil,	thickly fluid at —20	—	—
* Apple seed.	pale yellow,	odorless,	very mild,	0.9134	almond oil,	—14	—	—
* Apricot kernel	pale yellow,	odorless,	like almond oil,	0.9150	sesamé oil,	—15	—	—
* Areca nut	brownish,	peculiar,	peculiar,	0.978	tallow,	—	39–39.5	36
Becuiba tallow { expressed.	yellow-brown,	strongly aromatic,	tallowy,	0.9820	tallow,	—	42.5–43	32–32.5
extracted.	pale yellow,	slightly aromatic,	slightly spicy,					
* Beechnut.	pale yellow,	somewhat peculiar,	cold pressed, mild, warm pressed, harsh and sharp,	0.9225 (0.9188)	sesamé oil,	—16.5–17	—	—
† Belladonna seed.	golden yellow,	odorless,	mild,	0 9250	sesamé oil,	—27	—	—
* Ben	slightly yellowish.	odorless,	sweetish,	0.9120	almond oil,	± 0	—	—
Borneo tallow	greenish-yellow,	peculiar,	peculiar,	—	hard and crummy	—	35.5 (44)	—
Cacao butter	yellowish-white,	mild and agreeable,	mild and agreeable,	0.950–0.960	brittle.	—	30–32	20.5
† Camelina (German sesamé).	golden yellow,	like linseed oil,	like linseed oil,	0.9228	linseed oil,	—18.5 (white)	—	—
† Candle nut (Bankul nut) { expressed cold	pale yellow,	agreeable,	agreeable,	0.92325	semi-fluid,	+ 6	—	—
“ warm	brownish,	offensive,	offensive,	0.93625	thickly fluid,	—	22–23	—
* Cashew apple.	pale yellow,	odorless,	like almond oil,	0.9160	almond oil,	—	—	—
*† Castor { Indian	colorless or yellow,	peculiar,	mawkish, mild,	0.9633	very viscous,	—17 (18)	—	—
American.	traces of greenish,	peculiar,	mawkish, acrid,	0.9635	very viscous,	—11 (12)	—	—
* Ceylon oak (Nagkasur)	greenish-yellow,	peculiar,	peculiar,	0.9540	thinly fluid,	+ 5	—	—
* Charlock seed { crude	brownish-yellow,	earthy,	acrid,	0.9160	rape oil,	—19	—	—
refined	almost golden yellow,	somewhat earthy,	slightly earthy, acrid,	0.9150	rape oil,		—	—
Chaulmoogra.	pale brownish,	odorless,	tasteless,	0.955	soft,	—	35–36 (30)	15–16
* Cherry kernel.	golden yellow,	odorless,	mild, agreeable,	0.9184	almond oil,	—	—	—
Chinese tallow	white or greenish,	odorless,	tasteless,	0.948	hard,	—	44.5	35–36
Cocoanut { fresh	white,	peculiar,	agreeable,	0.9260	lard,	—	22–22.5	19–20.5
Copra { commercial	white,	acrid,	acrid,	0.9200	lard,		24–25	22
† Colocynth (bitter apple).	pale yellow,	odorless,	mild,	0.9200	rape oil,	1.25	—	—

GENERAL PHYSICAL PROPERTIES OF THE VEGETABLE FATS, OILS AND WAXES.—*Continued.*

Name of the Oil, Fat or Tallow.	Color.	Odor.	Taste.	Specific Gravity at 15° C.	Consistency at 15° C. like	Freezing Point, ° C.	Fusing Point ° C.	Solidifying Point ° C.
* Colza { crude	brownish-yellow,	peculiar,	peculiar.	0.9150	linseed oil,	—4, separates stearin,	—	—
refined	wine yellow,			0.9136		—6, yellow, butter-like,	—	—
Combo nut	yellow-brown,	aromatic,	aromatic, tallowy,	0.9740	tallowy,	—	40–41	30–30.5
* Cottonseed { crude	reddish-brown,	earthy,	acrid,	0.93025 (0.9230)	linseed oil,	+ 12, turbid,	—	—
refined	straw color,	earthy,	nutty,	0.9264 (0.9220)	sesamé oil,	± 0	—	—
Crabwood nut	whitish,	slightly acid, aromatic,	bitterish,	0.949	viscous at 20,	+ 10, soft, + 1, solid,	—	—
† Cress seed	brownish-yellow,	peculiar,	peculiar,	0.924 (0.9265)	sesamé oil,	—15	—	—
* † Croton	orange to brown-yellow,	disagreeable,	first mild, then pungent,	0.9426	castor oil,	—	—	—
† Cucumber seed	pale yellow,	almost odorless,	mild,	0.9231	almond oil,	—15	—	—
* Cyperus	golden-yellow,	agreeable,	nutty,	0.9240 (0.9187)	—	at + 3 separates stearin, solid at —2	—	—
Dika fat	white,	mild, cacao-like,	mild, cacao-like,	0.923	soft,	—	30–31	22–22.5
* Dragon-head seed	yellow,	slight,	like linseed oil,	0.9323	somewhat viscous,	—35	—	—
* Feuillia	yellow,	odorless,	mild.	0.9309	semi-fluid,	—	20	—
† Fir seed	brownish-yellow,	aromatic,	turpentine-like,	0.9312	quite viscous,	thickens at —16; white mass at—30	—	—
Fulwa butter	white,	odorless,	pure and mild,	0.9540	tallow,	—	48–49	35
Galam (Shea) butter	gray or greenish-white,	fresh, cacao-like, old, disagreeable,	fresh, cacao-like, old, disagreeable,	0.953 (0.938)	lard,	—	28–29	21–22
Goa butter (Kokum fat)	whitish, old, light yellow-gray,	cacao-like, rancid,	mild, oily, rancid,	— —	dry, friable,	— —	40–41 42.5–45	33 32
† Grape seed	pale yellow,	slight,	mild, somewhat bitter,	0.9202	rape oil.	—16	—	—
Hazelnut	pale yellow,	odorless,	agreeable,	0.9243	quite viscous,	—17–18	—	—
† Hemp seed	grayish-yellow to green-yellow,	peculiar,	peculiar,	0.9270 (0.930)	almond oil,	at —22 lard-like, solid at —27	—	—
† Hesperis	greenish,	odorless,	bitter,	0.9282	sesamé oil,	—22	—	—
† Hickory nut	pale yellow,	walnut-like,	walnut-like,	0.9245	sesamé oil,	—	—	—
† Horned poppy	pale yellow,	odorless,	tasteless,	0.9135	sesamé oil,	—17	—	—
* Horse chestnut	greenish-yellow,	rape-like,	bitter,	0.9231	sesamé oil,	+ 1.25	—	—

General Physical Properties of the Vegetable Fats, Oils and Waxes.—*Continued.*

Name of the Oil, Fat or Tallow.	Color.	Odor.	Taste.	Specific Gravity at 15° C.	Consistency at 15° C. like	Freezing Point, ° C.	Fusing Point ° C.	Solidifying Point ° C.
Japanese wax { natural	pale yellow,	resinous,tallowy, rancid,	resinous, tallowy, rancid,	1.000–1.006	solid { conchoidal,	—	52–55	40–41
Japanese wax { bleached	white efflorescence,			0.970–0.980	brittle,	—		
* Java almond	yellowish,	cacao-like,	cacao-like, sweetish,	0.919	semi-fluid.	—	20	—
† Kopak	pale yellow,	odorless,	agreeable,	0.9245 (0.936)	rape oil,	—	—	—
Korung	dark yellow,	peculiar,	bitter,	0.9450	semi-fluid,	+ 8	—	—
* Lallemantia	pale yellow,	almost odorless,	mild,	0.9336	linseed oil,	—30–35	—	—
Laurel	yellow-green	aromatic,	aromatic,	0.9331	soft,	—	33–36	24
† Lentiscus	dark green-yellow,	aromatic,	aromatic,	0.9310	semi-fluid,	+ 12	—	—
† Linseed { crude	brownish-yellow,	peculiar,	peculiar,	0.9360	—	—22	—	—
† Linseed { refined	brownish-yellow,	peculiar,	peculiar,	0.9290	—	—20	—	—
*† Madia { crude	dark yellow,	peculiar,	somewhat acrid,	0.9350	quite viscous,	expr. { cold —10	—	—
*† Madia { refined	golden yellow,	peculiar,	mild, nutty,	0.9286		warm —15	—	—
Mafura tallow	yellowish,	cacao-like,	tasteless,	—	solid,	—	42	36
Mahwa (Illipé) butter	pale greenish-yellow,	odorless,	fresh, agreeable, mild,	0.967	solid,	—	32–35	21–21.5
* Maize	pale to golden yellow,	peculiar,	agreeable,	0.9215	sesamé oil,	—10	—	—
† Mary thistle	pale yellow,	almost odorless,	agreeable, mild,	0.9213	poppy oil,	—20	—	—
* Mustard { black	brownish-yellow,	slightly like mustard,	mild.	0.9170	rape oil,	—15	—	—
* Mustard { white	golden yellow,	rape-like,	sharp,	0.9145	rape oil,	—16	—	—
Niam fat	reddish yellow,	peculiar,	peculiar,	0.951	solid,	—	35	30.5
Nutmeg	white and yellow-red marbled,	strongly aromatic,	peculiarly aromatic,	0.990	solid but brittle,	—	44–45	33
Ocuba wax	yellowish-white,	aromatic,	aromatic,	0.9250	solid,	—	39–40	35
* Olive { ordinary	green,	strong and disagreeable,	strong and disagreeable,	0.9200	+ 6° C. turbid,	+ 2 butter-like	—	—
* Olive { table	pale yellow,	peculiar,	mild,	0.9177 (0.9165)	+ 4–5° C. turbid,	—0 solid,	—	—
* Olive kernel	yellow,	mild and peculiar,	mild and peculiar,	0.9256	sesamé oil,	—13	—	—
Otoba	yellowish,	aromatic,	tallowy,	0.9300	solid,	—	38	31
Palm { fresh	yellow-red,	violet-like,	sweetish,	0.9450	solid,	—	28–30	21
Palm { old	faded,	rancid,	disagreeable,	0.9380	solid,	—	36–37	27
Palm kernel { fresh	white-yellowish,	agreeable,	agreeable,	0.952	solid,	—	25–26	20.5
Palm kernel { old	yellowish,	rancid,	rancid,	0.950	solid,	—	27–28	21

General Physical Properties of the Vegetable Fats, Oils and Waxes.—*Continued.*

Name of the Oil, Fat or Tallow.	Color.	Odor.	Taste.	Specific Gravity at 15° C.	Consistency at 15° C. like	Freezing Point, ° C.	Fusing Point ° C.	Solidifying Point ° C.
* Para nut	pale yellow,	odorless,	mild,	0.9185	almond oil,	—1	—	—
* Peach kernel	pale yellow,	odorless,	like almond oil,	0.915 (0.9193)	almond oil,	—18	—	—
* Peanut, expressed cold	slightly yellowish	odorless,	agreeable,	0.9180	rape oil,	—3	—	—
* Peanut, expressed warm	yellowish,	bean-like,	bean-like,	0.9202			—	—
† Pine seed	golden yellow,	aromatic turpentine-like,	aromatic, turpentine-like,	0.9288	quite viscous,	thickens at—15 white mass at —27	—	—
Piney tallow	faded green-yellowish,	slightly agreeable,	almost tasteless,	0.9450 (0.936)	almost tallowy,	—	36.5	36.5
* Pistachio nut	greenish,	aromatic,	mild,	0.9184	rape oil,	—	—	—
* Plum kernel	pale yellow,	odorless,	like almond oil,	0.9127	almond oil,	—8.5	—	—
Poon seed	dark green-yellow,	disagreeable,	disagreeable,	0.9420	viscous,	+ 5	—	—
† Poppy white	pale yellow to	peculiar,	agreeable,	0.9252 0.925	limpid,	—20 (18)	—	—
† Poppy blue	golden yellow,	slight,		0.9248			—	—
† Prickly poppy	orange-yellow,	odorless,	somewhat acrid,	0.9190	poppy oil,	—	—	—
† Pumpkin seed	brownish-yellow,	peculiar,	peculiar,	0.920	sesamé oil,	—20	—	—
* † Purgir nut	straw color,	almost odorless,	first mild, then pungent,	0.9152	± 0, turbid, solid at —12	—	—	—
* Radish seed	green-brownish-yellow,	slight,	mild, bitterish,	0.9175	rape oil,	—17.5	—	—
Rambutan tallow	pale yellow,	almost odorless,	tasteless,	—	—	—	65	—
* Rape, Spring, crude	green-brownish-yellow,	peculiar,	peculiar,	0.9147	viscous,	—4	—	—
* Rape, Spring, refined	wine yellow,	peculiar,	peculiar,	0.9130	viscous,	—5	—	—
* Rape, Fall, crude	green-brownish-yellow,	peculiar,	peculiar,	0.9157	viscous,	—2–3	—	—
* Rape, Fall, refined	wine yellow,	peculiar,	peculiar,	0.9132	viscous,	—5	—	—
* Rutabaga	greenish-brownish,	rape-like,	rape-like,	0.9162	viscous,	—	—	—
† Safflower seed	pale yellow,	slight,	mild,	0.9141	limpid,	—	—	—
* Sesamé	pale golden yellow,	odorless,	mild,	0.9235 (0.9242)	—	—5	—	—
Sesamé, warm pressed	brownish-yellow,	almost odorless,	acrid,	0.9250	—	—5	—	—
Sierra Leone butter	pale yellow,	slightly resinous,	peculiar,	0.9240	solid,	—	36–37	30
† Spruce fir seed	yellow,	balsamic,	mild,	0.9196 (0.9250)	rape oil,	—	—	—
* Spurge	pale yellow,	slight,	mild, then acrid,	0.9261	sesamé oil,	—11	—	—
* Stinking bean	pale yellow,	peculiar,	peculiar,	0.9230	viscous,	—3	—	—

General Physical Properties of the Vegetable Fats, Oils and Waxes.—*Concluded.*

Name of the Oil, Fat or Tallow.			Color.	Odor.	Taste.	Specific Gravity at 15° C.	Consistency at 15° C. like	Freezing Point, ° C.	Fusing Point ° C.	Solidifying Point ° C.
† Sunflower seed			pale yellow,	odorless,	mild,	0.9260	sesamé oil,	—16	—	—
Tangkallak fat			yellowish,	agreeable,	mild,	0.9450	solid,	—	45	—
* Tea seed			pale yellow,	peculiar,	disagreeable,	0.9140	limpid,	soft at —13	—	—
† Tobacco seed			pale green-yellow	odorless,	mild,	0.9232	hemp-oil,	—25	—	—
Tucum			cinnabar red,	slightly acid,	slightly acid,	0.9570	semi-liquid,	—	18–19	—
* Turnip seed (Rübsen)	Spring	crude	green-brownish-yellow,	peculiar,	peculiar,	0.9124	viscous,	—10	—	—
		refined	pale yellow,	peculiar,	peculiar,	0.9110	viscous,	—13	—	—
	Fall	crude	green-brownish-yellow,	peculiar,	peculiar,	0.9139	viscous,	—7.5	—	—
		refined	pale yellow,	peculiar,	peculiar,	0.9130	viscous,	—8	—	—
* Ungnadia			pale yellow,	odorless,	agreeable,	0.9120	limpid,	—10	—	—
Virola tallow			yellow,	nutmeg-like,	nutmeg-like,	0.9750	solid,	—	45	40
† Walnut	expressed cold		pale yellow or yellow,	odorless,	agreeable,	0.9250	limpid,	—28	—	—
	expressed warm		yellowish,	peculiar,	peculiar,	0.9268	limpid,	—	—	—
† Weld seed			dark greenish,	nauseous,	bitter,	0.9358	somewhat viscous,	—30	—	—
* Wild radish			brownish-yellow,	turnip-like,	first mild, then acrid,	0.9135	rape oil,	—8	—	—
† Wood oil, Chinese, expressed	cold		pale yellow,	odorless,	tasteless,	0.928	quite viscous,	—	—	—
	warm		brown,	penetrating,	disagreeable,	0.940	viscous,	—	—	—

General Physical Properties of the Animal Fats, Oils and Train Oils.

Oils non-drying. Train oils somewhat drying.

Name of the Oil, Fat or Tallow.		Color.	Odor.	Taste.	Specific Gravity 15° C.	Consistency at 15° C. like	Freezing Point ° C.	Fusing Point ° C.	Solidifying Point ° C.
Beef marrow		gray-yellowish,	odorless,	agreeable,	—	brittle,	—	45	35
Blackfish oil		pale yellow,	fishy,	fishy,	0.9180	liquid,	pasty at from + 5 to —3	—	—
Bone fat	fresh boiled	white-yellowish,	slight,	slight,	0.9165	soft,	—	21–22	15
	old extracted	brownish,	offensive,	offensive,	0.9185	quite solid,	—	23–24	17
Butter	fresh	yellowish to yellow,	peculiar,	agreeable,	0.925–0.935	soft,	—	31–31.5	19–20
	old	yellowish,	rancid,	disagreeable,	0.935–0.940	soft,	—	32–34	23–24
Coal fish oil		pale brown to brown,	like train oil,	like train oil,	0.9270	almost limpid,	—1	—	—
Egg oil		reddish-yellow,	almost odorless,	mild,	—	viscous,	+ 5	—	—
Eulachon oil		yellow-brownish,	fishy,	fishy,	0.907	liquid,	—	—	—
Goose grease		whitish,	peculiar,	agreeable,	0.9227	soft,	—	25–26	18
Herring dog oil		yellowish to brown,	fishy.	fishy,	0.905	limpid,	pasty at —2	—	—
Horse (neck) fat		dirty yellowish,	peculiar,	peculiar,	0.9160	viscous,	+ 10	—	—
Humpback (finback) oil		yellowish to brown,	fishy,	fishy,	0.915 (0.920)	liquid,	pasty at —3	—	—
Lard		white,	odorless,	somewhat sweetish,	0.9380–0.9400	consistency of butter,	—	32–33	26
Lard oil		pale yellow,	odorless,	mild,	0.9165	limpid,	—1 to —5	—	—
Liver oil	medicinal	pale yellow,	slightly fishy,	slightly fishy,	0.923	limpid,	0 to 1	—	—
	brown	pale brown to brown,	disagreeable,	fishy,	0.9240–0.9250	limpid,	0 to 1	—	—
Neat's foot oil		pale yellow,	slight,	mild,	0.913–0.917	limpid,	± 0	—	—
Porpoise oil		pale yellow to brownish,	fishy,	fishy,	0.9220	limpid,	—16	—	—
Ray oil		golden yellow,	like liver oil,	like liver oil,	0.9280	limpid,	+ 0	—	—
Right whale oil		pale brown to brown,	fishy,	fishy,	0.925–0.927	somewhat viscous,	—2	—	—
Sardel oil, Japanese		pale brown,	disagreeable,	disagreeable,	—	very viscous,	—	20–22	—
Seal oil	Archangel	pale to brown,	fishy,	fishy,	0.9155–0.9165	limpid,	pasty at + 3	—	—
	Greenland	pale to brown,	fishy,	fishy,	0.9190–0.9220	limpid,	pasty at + 5	—	—
	Newfoundland	pale to brown,	fishy.	fishy,	0.9126–0.9127	limpid,	pasty at + 4	—	—
	South Sea	pale to brown,	fishy,	fishy,	0.9130	slightly limpid,	pasty at + 5	—	—
Shark oil		pale yellow,	peculiar,	peculiar,	0.870–0.875	limpid,	—	—	—

GENERAL PROPERTIES OF THE ANIMAL FATS, OILS AND TRAIN OILS.—*Concluded.*

Name of the Oil, Fat or Tallow.	Color.	Odor.	Taste.	Specific Gravity at 15° C.	Consistency at 15° C. like	Freezing Point, ° C.	Fusing Point ° C.	Solidifying Point ° C.
Sperm whale oil	pale yellow,	fishy,	fishy,	0.9200	limpid,	—8	—	—
Spermaceti oil	yellow,	disagreeable,	peculiar,	0.910	limpid,	—25	—	—
Suet (ox tallow) fresh	almost white,	odorless,	tasteless,	0.9527	brittle,	—	42.5–43	33
Suet (ox tallow) old	pale yellow,	rancid,	disagreeable,	0.9532	brittle,	—	43.5	34
Tallow (sheep) fresh	white,	goatish,	peculiar,	0.9347	solid,	—	46.5	36
Tallow (sheep) old	gray-white,	rancid,	disagreeable,	0.9370	solid,	—	49.5	39.5
Walrus oil	pale brown,	fishy,	fishy,	0.925	somewhat viscous,	—2–3	—	—

GENERAL PHYSICAL PROPERTIES OF THE WAXES.

Names of Waxes.	Color.	Specific Gravity at 15° C.	Fusing Point, ° C.	Solidifying Point, ° C.	Consistency.
Balanophoreae	gray to yellow,	0.995	100	—	yellow bees' wax.
Bees'	yellow,	0.960–0.963	62–62.5	slightly below the fusing point,	tenacious brittle.
	white,	0.965–0.969	63–64		brittle.
Carnauba fresh	gray-yellow,	0.995	85–86	80–81	hard, brittle, friable to powder.
Carnauba old	gray-yellow,	0.999	87	81	
Chinese	white to yellowish,	0.970	82–83	80	hard, brittle.
Cow-tree	yellowish translucent,	—	50–52	—	soft, kneadable.
Fig (Getah)	reddish,	—	56–57	—	crummy,
Myrtle or bay-berry	green; old: gray-yellow,	1.000	45–46	—	harder than bees' wax.
Palm tree	yellow,	0.992–0.995	102–105	—	hard, brittle.
Spermaceti	white translucent,	0.943	50–54	nearly = fusing point,	friable.
Wool fat	—	0.973	39–40	—	smeary.

From the foregoing tables it will be seen how erroneous it is to associate the fusing point and the solidifying point, as is unfortunately the case in commerce.

Refraction.—If a ray of light, *i. e.*, the direction in which a wave of light progresses, passes from one medium into another, it is deflected from its original direction. The angle formed by the portion of the ray of light, penetrating into the second medium, with the prolongation of its former direction, or the deflection of the ray by refraction, is dependent on the nature of the two media, as well as on the color of the light, so that a ray of light, which is a mixture of several colors is by refraction decomposed to its elementary colors. For the passage of light of a single color, from air into a fixed fluid, the proportion between the sine of the angle of incidence and the angle of refraction is constant independent of the magnitude of the angle of incidence: $\frac{\sin i}{\sin \beta} = n$. i.= angle of incidence, β = angle of refraction, n = proportion of fraction.

This proportion changes with the nature of the fluid and must therefore be considered a characteristic property, which is called the *index of refraction.*

Opinions are much divided regarding the value of optical methods for obtaining reliable points in judging the purity of a fat. Strohmer[*], especially, is of the opinion that the refractive indices of oils depend too much on their age and the mode of obtaining them. On the other hand, Alexander Müller[†] and Skalweit,[‡] recommend the use of a refractometer for the examination of butter, and Amagat and Jean,[§] consider this method of testing of great importance for the examination of fluid and solid fats, and especially also of butter.

For the determination of the index of refraction, *Abbé's Refractometer*, Figs. 30 and 31, is made use of. It consists essentially of a double prism, a telescope, an arrangement for measuring the angle and a compensator. The instrument is easy of manipulation, and but little time for making the examination is required. Although the test can only be a comparative one, adulteration of oils, etc., may be established by the refractometer.

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[*] Zeitschrift für Zuckerindustrie, 1889, 189.

[†] Archiv der Pharmacie, 1886, 210.

[‡] Repertorium der analytischen Chemie, 1886, 181 and 235.

[§] Compt. rend., 1889, 109, 616; and Mon. scientif. 1890, 215 and 1890, 346.

FIG. 30.

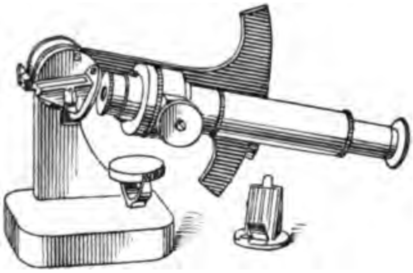
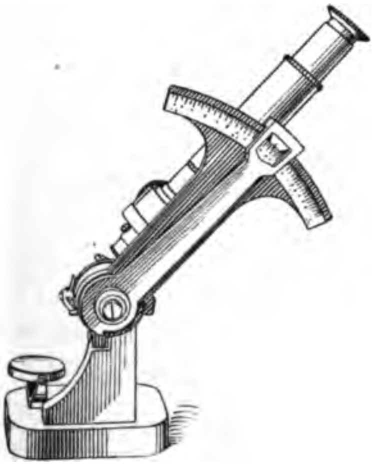


FIG. 31.



ABBÉ'S REFRACTOMETER.

The apparatus is operated as follows: Fine tissue paper of rather heavy body is cut into rectangular pieces 3 centimeters in length by 1.5 centimeters in breadth. One of these pieces of paper is placed on the lower of the two glass prisms of the apparatus. Two or three drops of the oil or the fat to be examined are placed upon the paper and the upper prism carefully placed in position so as not to move the paper from its place. In charging the apparatus with the oil in this way it is placed in the horizontal position. After the paper disk holding the fat is secured by replacing the upper prism, the apparatus is placed in its normal position and the index moved until the light directed through the apparatus by the mirror shows the field of vision divided into dark and light portions. The dispersion apparatus is now turned until the rainbow colors on the part between the dark and light field have disappeared. Before doing this, however, the telescope, the eye-piece of the apparatus, is so adjusted as to bring the cross-lines of the field of vision distinctly into focus. The index of the apparatus is now moved back and forth until the dark edge of the field of vision falls exactly in the intersection of the cross-lines. The refractive index of the fat under examination for the Frauenhofer line *D* is then directly read upon the scale by means of a small magnifying glass. To check the accuracy of the first reading, the dispersion apparatus should be turned through an angle of 180° until the colors have again disappeared, and the scale of the instrument is again read. These two readings should fall closely together, and their mean is the true reading of the fat under examination.

With solid fats it has to be taken into consideration that the index of refraction cannot be taken at the ordinary room temperature, but must be determined at temperatures at which they remain fluid. The fat is melted, and after thorough stirring a drop of it is placed upon the prism and the refractometer placed in a room having the desired temperature, for instance, 122° F. The temperature should be maintained at a constant point. The apparatus may also be placed on the top of an air-bath maintained at a constant temperature, and should be allowed to remain on the bath for at least one hour before work is commenced. If necessary it can be protected with a hood, the side next to the window being provided with an opening for admitting the light, and the one next the operator being entirely open. The thermometer should rest with the bulb as closely as possible applied to the metallic casing of the prisms of the instrument. The temperature marked by it is much lower than that of the space between the prisms occupied by the film of fat under examination.

When the temperature of the refractometer on the air-bath has become constant, the refractive index is read off at that temperature and reduced to the standard of 25° C. (77° F.) Since the refractive power decreases with a rising temperature, the values determined at higher temperatures have to be correspondingly increased. H. W. Wiley gives the factor for each degree C. as 0.000176. If, for instance, the refractive index of butter-fat at 32.4° C. has been found = 1.4540, it has to be increased $32.4 - 25 = 7.4 \times 0.000176 = 0.0013$, hence = 1.4553. If instead of the normal number 1.3330, water at 25° C. has only shown 1.3300, 0.0030 is added, the refractive index at 25° C. thus being 1.4583.

The appended table contains the refractive indices of various oils at 20° C., according to Abbé.

REFRACTIVE INDICES OF VARIOUS OILS.

At 20° C. Water = 1.3330.

Names of Oils.	Index.	Names of Oils.	Index.
Almond oil	1.4810	Lubricating oil, Russian	1.4870
Beechnut oil	1.5000	Olive oil	1.4690
Butter olein	1.4638	Paraffin oil	1.4740
Castor oil	1.4900	Petroleum	1.4750
Cod-liver oil	1.4800	Poppy oil	1.4670
Colza oil	1.4750	Rape-seed oil	1.4720
Cotton-seed oil, crude	1.4732	Right whale oil	1.4830
Cotton-seed oil, refined	1.4748	Spermaceti oil	1.4700
Fish oil	1.4750	Walnut oil	1.4910
Linseed oil	1.4780		

REFRACTIVE INDICES OF FATS.

Names of Fats, etc.	Index.
Fused:	
Tallow	1.460
Wax, yellow	1.453
Wax, white	1.462
Spermaceti	1.446

Strohmer* has determined the refractive indices of a number of oils with Abbé's refractometer. From the appended table drawn up by him, it will be seen that the drying oils possess considerably greater refractive power than the non-drying oils; castor oil alone having a refractive index, close to that of the drying oils. Of the non-drying oils, olive oil has the lowest refractive index, the latter, however, appearing to be also dependent on the age and mode of obtaining the oil. For an explanation of the table, it may be remarked that the column, *d*, gives the differences between the refractive indices of the oils and of water, thus being independent of small adjusting errors of the apparatus. On the other hand, the readings must be at the temperatures for which the table is designed, the refractive indices of oils being more influenced by variations in temperature than the refractive index of water.

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* Zeitschrift für Zuckerindustrie, 1889, 189.

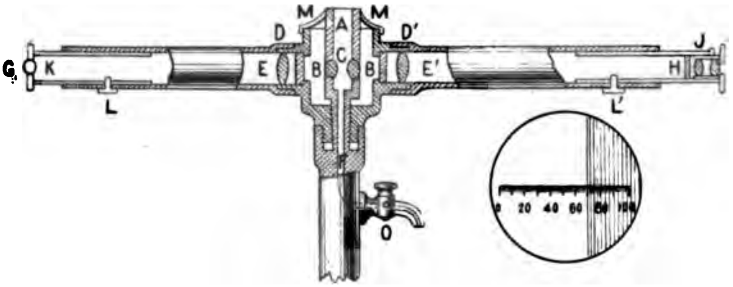
TABLE OF REFRACTIVE INDICES OF OILS ACCORDING TO STROHMER.

Oil or Fat.	Remarks.	Refractive Index. At 16° C. ^nD 16° C.	Refractive Index. At 14° C. ^nD 14° C.	Refractive Index. At 15° C. mean from a. and b. ^nD 15° C.	Difference between the refractive index of the oil and of water at 15° C.
		a.	b.	c.	d.
Olive oil	Virgin oil from Triest...	1.4700	1.4696	1.4698	0.1368
Olive oil	Dalmatia inferior oil....	1.4702	1.4704	1.4703	0.1373
Sesamé oil.......	Fresh	1.4748	1.4748	1.4748	0.1418
Sesamé oil.......	French, 9 years old.....	1.4755	1.4768	1.4762	0.1432
Cotton-seed oil ...	American, best quality ..	1.4743	1.4761	1.4752	0.1422
Cotton-seed oil ...	Trade Mark, Marginis ..	1.4729	1.4734	1.4732	0.1402
Cotton-seed oil ...	From Triest, 7 years old.	1.4735	1.4751	1.4743	0.1413
Colza oil	3 years old............	1.4733	1.4731	1.4732	0.1402
Colza oil	Freed from acid........	1.4718	1.4721	1.4720	0.1390
Rape oil	Refined, 7 years old.....	1.4727	1.4725	1.4726	0.1396
Rape oil	Pressed from fall rape...	1.4747	1.4767	1.4757	0.1427
Castor oil........	Cold pressed...........	1.4786	1.4803	1.4795	0.1465
Castor oil........	Warm pressed.........	1.4809	1.4796	1.4803	0.1473
Linseed oil.......	Cold pressed...........	1.4834	1.4836	1.4835	0.1505
Poppy oil.......	—	1.4779	1.4787	1.4783	0.1453
Liver oil.........	Möller's original........	1.4841	1.4862	1.4852	0.1522
Liver oil.........	Blonde	1.4791	1.4809	1.4800	0.1470
Cod-liver oil	—	1.4785	1.4792	1.4789	0.1459
Fish oil	—	—	1.4790	1.4790	0.1460
Water	—	1.3330	1.3330	1.330	—
Petroleum	Kaiseröl. sp. gr. 0.7897 at 15° C.............	—		1.4376	0.1046
Mineral lubricating oil.........	Russian, sp. gr. 0.9058 at 15° C...............	—		1.4942	0.1612
Mineral lubricating oil.........	Sp. gr. 0.9066 at 15° C..	—		1.9443	0.1613

In the Paris Municipal Laboratory an *oleorefractometer* with a special scale, Fig. 32, constructed by Amagat and Jean, is used for the determination of the refractive power of oils.

The cylindrical metalic vessel *B* is provided with two apertures opposite to one another, which are closed by the glass plates *D D*, in front of which are placed the lenses *E E*. Over the tubes containing the lenses are pushed the metallic tubes *L L*, one of them being on one end provided with the sight *G*, while the other holds the telescope J. Inside of the tube in front of the lens is placed a photographic scale *H*. A valve *K* in *G*, divides the incident ray of light into two portions, one of which is somewhat shaded. From the position of the dividing line of light and shadow the deflection of the light is read off. A gas flame serves as the source of light. In the centre of the vessel *B*, is placed another cylindrical vessel *A*, in the walls of which two glass-plates *C*, are so arranged as to form the sides of a prism. Both vessels are provided with outlet contrivances. If both vessels are filled with the same kind of fluid, the shadowy boundary is thrown by the prism upon the *O* point of the scale. For the outer vessel Jean uses an oil mixture which does not deflect light. Before making the test, both vessels are filled with this oil mixture, and the shadowy boundary fixed at *O*, if it does not fall there by itself. The inner vessel is then emptied and filled with the sample of oil to be tested. The temperature of the sample of oil is brought to and maintained at 22°C. (71.6° F.), by warm water in the jacket surrounding the vessel. The deflection is read off from a scale divided into 100 degrees. The following oils have been examined with this apparatus:

FIG. 32.



AMAGAT AND JEAN'S OLEOREFRACTOMETER.

A B, metallic vessels; *C D D*, glass-plates; *E E*, lenses; *F*, tube; *G*, sight; *H*, scale; *J*, telescope; *K*, valve; *L L*, metallic tubes; *M*, valves; *O*, tap.

REFRACTIVE INDICES OF VARIOUS OILS WITH THE OLEOREFRACTOMETER.

Names of Oils.	Scale—degrees.	Names of Oils.	Scale—degrees.
Almond oil...........	+6.5	Neat's foot oil	—3.0
Butter................	—35.0	Oleic acid	—34.0
Castor oil............	+40.0	Olive oil	+1.5–2.0
Colza oil.............	+16.5–17.5	Peanut oil............	+4.5
Cotton-seed oil........	+20.0	Poppy oil	+30.0–34.0
Hempseed oil	+33.0	Sesamé oil............	+17.0
Horse-foot oil	—12.0	Sheep's trotter oil	—10.0
Lard oil	—12.5	Spermaceti oil	—12.0
Linseed oil...........	+53.0	Suet (ox tallow)	—16.0
Maize oil	+27.0	Tallow (sheep)	—20.0
Margarin	—15.0		

According to the above table, vegetable oils give deflections to the right and animal oils to the left. Rosin oil added to vegetable oils may be recognized by the decrease in deflection.

Lobry de Bruijn and Von Leent*, have obtained with various fats deflections which, with the exception of sesamé oil, satisfactorily agreed with those observed by Jean.

Spectrum phenomena.—J. Müller sometime ago noticed, that many vegetable oils show the chlorophyl ribbon, and that it may be recognized in a mixture of vegetable oils with foreign substances, for instance animal oils.

Olive and linseed oils give three absorption spectra, one very dark into red, a slight one into orange, and a somewhat stronger one into green. *Sesamé oil* only shows a slight ribbon into red, and *castor oil* none.

Doumer† divides the oils according to their spectra into four groups:

1. Oils whlch give the spectrum of chlorophyl: Olive, hemp-seed, nut oils.

2. Oils which absorb no portion of the spectrum: Castor oil, almond oil (from sweet as well as from bitter almonds).

3. Oils which absorb all chemically active rays: Red, orange, yellow and half of the green remain unchanged; all the rest is absorbed: Rape, colza, linseed, mustard oils.

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* Revue internat. des fats., 1891, 4, 84.

† Chemiker Zeitung, 9, 534.

4. This group seems to be a modification of 3. The absorption appears in ribbons in the chemically active part of the spectrum: Sesamé, peanut, poppy, cotton-seed oils.

The absorption-spectra observed depend, of course, on the nature of the coloring matter in the oils, and for this reason this method possesses no greater degree of reliability than the color reaction appearing in mixing oils with acids, alkalies, etc.

Action of polarised light. Bishop* and Peter,† test liquid fats in a Laurent polarimeter, in a tube 20 centimeters long, at 13° to 15° C. (55.4 to 59° F.). Turbid oils are first filtered, and dark oils decolorized with animal charcoal.

POLARIZING POWER OF SOME OILS.

Names of Oils.	Specific Gravity at 59° F.	Deviation, 59° F.	
		Right.	Left.
Almond oil	0.9185	—	−0.2
Apricot kernel oil	0.9150	—	−0.2
Castor oil	0.9163	+9.8	—
Charlock seed oil	0.9150	—	—
Cod-liver oil medicinal pale yellow	0.9210	+0.7	—
yellow	0.9230	+0.5	—
Colza oil	0.9110	—	−0.3
Cotton-seed oil, purified	0.9263	—	—
Linseed oil	0.9290	—	−0.2
Olive oil, table	0.9177	+0.2	—
Peanut oil	0.9180	—	−0.1
Poppy-seed oil	0.9252	+0.1	—
Rosin oil	0.9000	+31.0	—
Seal oil	0.9160	—	—
Sesamé oil	0.9122 0.9123	+1.1 +1.0	— —

According to Peter's investigations, most vegetable oils are slightly levogyrate, especially almond, colza, hemp-seed, linseed and poppy seed oils. Nut oil is inactive, peanut oil generally levogyrate and sometimes slightly dextrogygrate. More than 100 samples of olive oil proved slightly dextrogyrate, so that adulterations with the oils named are claimed to be recognizable by the altered power of rotation. Remarkable, however, is the high power of rotation of croton oil (+43° by the saccharometer), and of castor oil (+40.70).

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* Jour Phar. Chim. 16, 300.

† Chem. Zeitung, 1887, 267.

Microscopical examination. The use of the microscope for the examination of oils and fats has not been sufficiently perfected to allow of general rules being given. Particulars are found under the separate fats, etc.

Electrical conductivity. The solid fats are non-conductors of electricity, the fat oils bad conductors, like olive oil, or semi-conductors, like poppy-seed oil, etc. Various attempts to utilize the conducting power of oils for the purpose of detecting adulterations have been made, especially by Palmieri, who has constructed a special instrument, called a *diagometer*, with which it is claimed olive oil can be readily tested as to its purity.

CHAPTER V.

CHEMICAL CONSTITUTION, CHEMICAL DECOMPOSITION, ETC., OF FATS AND OILS.

I. Chemical Constitution.

THE fats and fixed oils constitute a well marked and important group of organic compounds, which exist abundantly both in the animal and vegetable kingdoms. A remarkable feature in their history is the close resemblance in chemical composition and properties which exists between them; one of their principal characteristics being that they are rich in carbon and hydrogen and poor in oxygen. The vegetable fats are identical with those occurring in the animal kingdom, and differ from the mineral oils by their greater content of oxygen, some of the latter containing only traces of oxygen in the form of naphthene acid = $C_nH_{2n-1}O_2$.

Of the animal fats, horse fat shows the highest content of carbon, and butter fat the lowest. This is explained by the fact that beside the glycerides of the acids with a high content of carbon, there are present, in butter, glycerides of the acids with a low content of carbon, as butyric acid and capric acid. It is not known to which glycerides the high content of carbon in horse fat is due.

The organic oils contain on an average:

Carbon, 76 to 79 per cent.
Hydrogen, 11 to 13 per cent.
Oxygen, 10 to 12 per cent.

ELEMENTARY COMPOSITION OF SOME FATS AND OILS.

Name of Fat or Oil.	Carbon per cent.	Hydrogen per cent.	Oxygen per cent.
Beech nut oil	75.11	11.06	13.83
Bees wax	81.80	12.67	5.54
Butter fat	75.63	11.87	12.50
Chinese tallow	82.31	13.57	4.12
Cacao butter	75.20	11.90	12.90
Cod-liver oil	75.91	12.12	11.87
German sesamé oil	76.80	11.50	11.70
Hemp oil	76.00	11.30	12.70
Herring dog oil	79.86	13.36	6.77
Horse fat	77.07	11.69	11.24
Human kidney fat	76.80	11.94	11.26
Lard	76.54	11.94	11.52
Linseed oil	78.00	11.00	11.00
Olive oil	77.20	11.30	11.50
Poppy-seed oil	76.63	11.63	11.74
Rape-seed oil	77.21	13.36	9.43
Spermaceti	80.18	13.22	6.60
Suet (ox tallow)	76.50	11.91	11.59
Tallow (sheep)	76.61	12.03	11.36

Since the carbo-hydrates are considerably richer in oxygen than the fats and oils, the conversion into starch or sugar taking place during germination must necessarily be dependent on an oxidizing process connected with the absorption of oxygen.

All vegetable and animal fats, with the exception of spermaceti and wax, contain chiefly as principal constituents a mixture in various proportions of three varieties of fat, namely the glycerides *stearin*, *palmitin*, *olein*, etc., their consistency being also dependent on them.

The solid fats contain chiefly stearin and palmitin, the softer varieties of fat, grease, or butter, a mixture of stearin and palmitin with olein, and the fat oils, predominantly olein.

The principal elucidation of the nature of the fats we owe to the labors of Chevreul, which commenced in 1812, and culminated in 1823 in the publication of his work, "*Recherches sur les Corps gras d'Origine Animale.*" Since then others, and particularly Bertholet, have extended his researches, and in the main confirmed their correctness.

According to Chevreul's investigations and the former dualistic theory, fats were considered salts, and written analogous in composition to inorganic salts. The hypothecial tribasic radical "lypyl" = $(C_6H_6)O_3$ was, according to Berzelius, accepted as the basis in the fats, which on decomposing fat with soda or potash absorbs, at the moment of liberation, water, and forms lypyl hydrate or glycerin = $(C_6H_5)O_3.3HO$.

$$\underset{\text{ferric hydrate}}{Fe_2O_3.3HO} - \underset{\text{lypyl hydrate}}{(C_6H_5)O_3.3HO}$$

Hence according to the former theory:
Stearin = lypyl stearate
Palmitin = lypyl palmitate
Olein= lypyl oleate.

Some fats, as castor oil, cocoanut oil, peanut oil, etc., contain special peculiar acids fixed on lypyl.

That lypyl absorbs water and thereby forms lypyl hydrate or glycerin, is shown by the examination of fats. If a fixed quantity of fat, previously completely dried, is treated under heat with potash or soda in the presence of water, decomposition takes place and a salt—sodium stearate—is formed, from which the fatty acid may be separated by the addition of hydrochloric or dilute sulphuric acid, lypyl hydrate = glycerin remaining behind in the fluid. The latter is evaporated to dryness at 140° F. and from the residue the glycerin extracted with absolute alcohol, carefully evaporated, and weighed. If now the separated fatty acid, previously dried, is also weighed, the sum total of both weights—of the glycerin and fatty acid—is not equal to that of the fat used, but a few per cent. higher, the latter corresponding to the water absorbed.

Name of Fat or Oil.	Glycerin.	Fatty Acids.	Total.
Goose grease	8.20 per cent.	94.40 per cent.	102.60 per cent.
Lard....................	8.82 "	95.90 "	104.72 "
Linseed oil..............	9.50 "	95.50 "	105.00 "
Olive oil, second quality...	8.62 "	96.53 "	105.15 "
Suet (ox tallow).........	8.21 "	96.86 "	105.07 "
Tallow (sheep)	8.00 "	95.00 "	103.00 "

Theoretically stearin should yield 106 per cent. stearic acid and glycerin, but in the saponification of fat the total sum always varies very much, because all the bodies in the fat are not saponified. 1 equivalent stearin = 890 parts by weight absorbs 6 equivalents water = 54 parts by weight, and yields 1 equivalent glycerin = 92 parts by weight and 3 equivalents stearic acid = 852 parts by weight. The total of glycerin + stearic acid is $92 + 852 = 944$. Hence 890 parts stearin yield a product of 994 parts or $\frac{944 \times 100}{890} = 106.06$ per cent.

However, in the fats, wax, spermaceti and wool fat, non-saponifiable substances are present, which consist partially of mucus, cholesterin and hydrocarbons; hence the difference.

NON-SAPONIFIABLE SUBSTANCES IN FATS, OILS AND WAXES.

Name of Oil, etc.	Content, per cent.	Name of Oil, etc.	Content, per cent.
Almond oil	0.45	Olive oil, yellow ...	0.80
Bees' wax	52.50	" green ...	1.50
Cocoanut oil.......	0.80	Palm oil..........	1.25
Cotton-seed oil.....	1.85	Poppy seed oil	1.15
Hemp-seed oil	1.00	Rape oil, crude....	1.30
Japanese wax	1.20	" refined ..	0.25
Lard..............	0.30	Sesamé oil	0.35
Linseed oil	1.10	Spermaceti........	40.50
Liver oil, pale......	0.30	Tallow	0.50
" brown ...	1.45		

In the formulæ above given $C = 6$, $O = 8$; however, in the succeeding formulæ the atomic weights, $C = 12$, $O = 16$, etc., are valid.

The opinion already expressed by Chevreul in 1822, that the fats are not only salt-like combinations, but combinations corresponding to compound ethers, has been confirmed and is now generally accepted.

Chevreul found that by treating fats with bases—potassium hydroxide, KOH (caustic potash), or sodium hydroxide, NaOH (caustic soda)—they split into acid, which, with a portion of the modified water, NaOH remains united with the sodium = Na, while the rest assists in forming hydroxyl =(OH) alcohol.

$$\underset{\text{stearin}}{\underline{(C_{17}H_{35}COO)_3C_3H_5'''}} + \underset{\text{sodium hydroxide}}{\underline{3NaHO}} = \underset{\text{sodium stearate}}{\underline{3C_{17}H_{35}COO.Na}} + \underset{\text{glycerin.}}{\underline{C_3H_5'''(OH)_3}}$$

The decomposition of fat by an alkali does, however, not take place suddenly and throughout the entire mass, as is the case with an inorganic salt, but has to pass through several phases, for the explanation of which, and also to show the artificial formation of fats, it is necessary to briefly refer to general organic chemistry.

An entire series of combinations, called "fatty bodies" or "marsh-gas derivatives," are united in one group. The term "fatty bodies" is applied because the natural fats and allied combinations belong to this group.

With the first fundamental hydrocarbon—marsh gas or methane, CH_4—is associated an entire series of hydrocarbons having the general formula C_nH_{2n+2}. The lowest members of this series are gases, the medium ones colorless liquids regularly increasing in boiling point, and the highest solid crystalline bodies called paraffines.

HYDROCARBONS OF THE METHANE SERIES C_nH_{2n+2}.—SERIES OF THE NORMAL ETHANES OR NORMAL PARAFFINS.

Name.	Formula.	Boiling Point.	Specific gravity.
Methane	CH_4	Gas	0.55
Ethane	C_2H_6	"	1.036
Propane	C_3H_8	"	—
Butane	C_4H_{10}	10 C.	0.600
Pentane	C_5H_{12}	37.39° C.	0.628
Hexane	C_6H_{14}	70.5 "	0.668
Heptane	C_7H_{16}	98.4 "	0.669
Octane	C_8H_{18}	125 "	0.703
Nonane	C_9H_{20}	148 "	0.741
Decane	$C_{10}H_{22}$	182 "	0.765
Endecane	$C_{11}H_{24}$	202 "	0.776
Dodecane	$C_{12}H_{26}$	216 "	0.792
Tridecane	$C_{13}H_{28}$	238 "	—
Tetradecane	$C_{14}H_{30}$	258 "	—
Pentadecane	$C_{15}H_{32}$	278 "	—
Hekdecane	$C_{16}H_{34}$	—	—
Octodecane	$C_{18}H_{38}$	—	—
Eicosane	$C_{20}H_{42}$	—	—
Tricosane	$C_{23}H_{48}$	—	—
Pentacosane	$C_{25}H_{52}$	—	—
Heptacosane = Paraffin	$C_{27}H_{56}$	—	—
Paraffin	$C_{30}H_{62}$	370 C.	--

Each member of the above series differs from the preceding by CH_2. Such a series is called a homologous series.

The chemical character of all members of a homologous series is the same, *i. e.*, they are either all hydrocarbons, or all alcohols, or all acids, etc.

The above hydrocarbons only occur ready formed in American petroleum.

These hydrocarbons cannot absorb any further atoms of hydrogen, and are, therefore, termed "saturated hydrocarbons." Their radical,

Methyl	CH_3,
Ethyl	C_2H_5,
Propyl	C_3H_7, etc.,

is univalent as a distinction from the "non-saturated hydrocarbons" of the general formula C_nH_{2n}:—

Ethene or olefiant gas	C_3H_6,
Propylene	C_3H_6,
Butylene	C_4H_8,
Amylene	C_5H_{10}, etc.,

whose radicals are dyads, and which by the absorption of hydrogen can be converted into saturated combinations. Further non-saturated hydrocarbons of the formula C_nH_{2n-2}, are:—

Acetylene	C_2H_2
Allylene	C_3H_4
Crotonylene	C_4H_6
Valerylene	C_5H_8.

In the saturated hydrocarbons the hydrogen can, however, be replaced by other elements, for instance, chlorine, bromine, iodine, etc., whereby homologous series of derivatives of chlorine, bromine, iodine, etc., are formed.

CH_4 methane,
CH_3Cl methyl chloride,
CH_2Cl_2 methylene chloride,
$CHCl_3$ methylene chloroform,
CCl_4 carbon tetrachloride,

C_2H_6 ethane,
C_2H_5Cl ethyl chloride,
$C_2H_4Cl_2$ ethylidene chloride,
$C_2H_3Cl_3$ ethylene chloroform, or ethyl trichloride.

C_3H_8 propane
C_3H_7Cl propyl chloride
$C_3H_6Cl_2$ propylene chloride
$C_3H_5Cl_3$ propyl trichloride.

The non-saturated hydrocarbons treated with chlorine, bromine, or iodine are first converted by absorption into saturated combinations, substitution taking place later on.

With these chlorine combinations one is enabled to form the alcohols, acids, ethers, compound ethers, or esters.

By the action of methyl or ethyl chloride upon a modified water, such as sodium hydroxide NaOH, a split takes place, sodium chloride being formed and the hydroxyl HO combining with a radical of the methane series to a monatomic alcohol.

$$\frac{CH_3Cl}{\text{Methyl chloride}} + \frac{NaOH}{\text{Sodium hydroxide}} = \frac{NaCl}{\text{Sodium chloride}} + \frac{CH_3'OH}{\text{METHYL ALCOHOL.}}$$

$$\frac{C_2H_5Cl}{\text{Ethyl chloride}} + \frac{NaOH}{\text{Sodium hydroxide}} = \frac{NaCl}{\text{Sodium chloride}} + \frac{C_2H_5'OH}{\text{ETHYL ALCOHOL.}}$$

MONOHYDROXYL DERIVATIVES = ALCOHOLS OF THE METHANE SERIES.

Monohydric alcohols.	Formula.	Boiling point, Fusing point.
Methyl alcohol (wood spirit)	CH_3OH	60° C.
Ethyl alcohol (spirits of wine)	C_2H_5OH	78° "
Propyl alcohol	C_3H_7OH	97° "
Butyl alcohol	C_4H_9OH	116° "
Amyl alcohol (fusel oil)	$C_5H_{11}OH$	135° "
Hexyl alcohol	$C_6H_{13}OH$	154° "
Octyl alcohol	$C_8H_{17}OH$	192° "
Cetyl alcohol (in spermaceti)	$C_{16}H_{33}OH$	49–49.5° "
Ceryl alcohol (in wax)	$C_{27}H_{55}OH$	79° "
Myricyl alcohol (in wax)	$C_{30}H_{61}OH$	85° "

When hydrocarbons containing two substituted atoms of chlorine are treated in the same manner with an alkali, diatomic *alcohols* or *glycols* are formed by the substitution of one equivalent of hydroxyl for each atom of chlorine.

$$\frac{C_2H_4''Cl_2}{\text{Ethene dichloride}} + \frac{2NaOH}{\text{Sodium hydroxide}} = \frac{2NaCl}{\text{Sodium chloride}} + \frac{C_2H_4''(OH_2)}{\text{Ethene alc.}=\textsc{Glycol}.}$$

$$\frac{C_3H_6''Cl_2}{\text{Propene dichloride}} + \frac{2NaOH}{\text{Sodium hydroxide}} = \frac{2NaCl}{\text{Sodium chloride}} + \frac{C_3H_6''(OH_2)}{\text{Propene glycol.}}$$

DIHYDROXYL DERIVATIVES OF THE HYDROCARBONS "GLYCOLS."

	Formula.	Formula.	Boiling point.
Ethene glycol	$C_2H_4(OH)_2$	$H_2(CH_2OH)_2$	197.5° C.
Propene glycol........... ..	$C_3H_6(OH)_2$	$CH_3(CH_2OH)_2$	188° "
Butene glycol..............	$C_4H_8(OH)_2$	$C_2H_5(CH_2OH)_2$	184° "
Amylene glycol	$C_5H_{10}(OH)_2$	$C_3H_7(CH_2OH)_2$	177° "

The same decompositions may be extended to three atoms of chlorine which are replaced by hydroxyl, and a triatomic alcohol—*glycerin* = *propenyl alcohol* is formed, besides which are also known *butyl glycerin* and *amyl glycerin.*

The *alcohols* or *carbinols* are therefore hydrocarbons in which one, two, three or more atoms of hydrogen have been replaced by the hydroxyl group (HO). They are neutral combinations, showing neither a basic nor an acid reaction. Most of them are colorless, volatile fluids, sometimes inflammable, of an alcoholic odor and intoxicating effect; some are viscous and syrupy, for instance glycerin, while some form solid crystalline combinations, for example mannite.

By complete oxidation through the absorption of oxygen the alcohols are converted into fatty acids; there being, however, an intermediate product, termed "*aldehyde.*" The aldehydes are formed from the alcohols by the elimination of two atoms of hydrogen from the carbinol group (CH_2–OH), the non-saturated group (COH) = *carbonyl,* being characteristic of them. The aldehydes of the formula $C_nH_{2n}O$ = ethyl aldehyde = $C_2H_4O = CH_3.COH$ are combinations which do not occur in natural fats.

Finally the acids are derived from the alcohols by the two atoms of hydrogen of the carbinol group ($CH_2.OH$), which are combined with the atom of carbon, being replaced by one atom of oxygen, whereby the *carbon group* ($COOH$), which is characteristic for the acids, is formed.

$$\frac{H.CH_2OH}{\text{Methyl alcohol}} + \frac{2O}{\text{Oxygen}} = \frac{HOH}{\text{Water}} + \frac{H{-}COOH}{\text{Formic acid.}}$$

$$\frac{CH_3.CH_2OH}{\text{Ethyl alcohol}} + \frac{2O}{\text{Oxygen}} = \frac{HOH}{\text{Water}} + \frac{CH_3.COOH}{\text{Acetic acid.}}$$

$$\frac{C_{15}H_{31}.OH}{\text{Cetyl alcohol}} + \frac{2O}{\text{Oxygen}} = \frac{HOH}{\text{Water}} + \frac{C_{15}H_{31}.COOH}{\text{Palmitic acid.}}$$

CARBON DERIVATIVES OF THE HYDROCARBONS, CARBON ACIDS.

Monobasic Acids, $C_nH_{2n}+O_2$.	Formula.	Boiling Point, Fusing Point.	
Formic acid	CH_2O_2	99°	C.
Acetic acid	$C_2H_4O_2$	118°	"
Propionic acid	$C_3H_6O_2$	137°	"
Butyric acid (in butter)	$C_4H_8O_2$	156°	"
Valeric acid (in rancid vegetable fats)	$C_5H_{10}O_2$	175°	"
Caproic acid (in cocoanut oil)	$C_6H_{12}O_2$	194°	"
Oenanthylic acid	$C_7H_{14}O_2$	213°	"
Caprylic acid (in butter, cocoanut oil)	$C_8H_{16}O_2$	232°	"
Pelargonic acid (in pelargonium oil)	$C_9H_{18}O_2$	251°	"
Capric acid (in butter)	$C_{10}H_{20}O_2$	39.0°	"
Lauric acid (in bay oil)	$C_{12}H_{24}O_2$	43.6°	"
Myristic acid (in nutmeg butter)	$C_{14}H_{28}O_2$	53.8°	"
Palmitic acid (in lard, etc.)	$C_{16}H_{32}O_2$	62.0°	"
Stearic acid (in tallow, etc.)	$C_{18}H_{36}O_2$	69.2°	"
Arachidic acid (in peanut oil)	$C_{20}H_{40}O_2$	73.0°	"
Behenic acid (in ben oil)	$C_{22}H_{44}O_2$	75.0°	"
Carnaubic acid (in carnauba wax)	$C_{24}H_{48}O_2$	72.5°	"
Cerotic acid (in bees' wax)	$C_{27}H_{54}O_2$	78.0°	"
Melissic acid (in bees' wax)	$C_{30}H_{60}O_2$	88.0°	"
(Theobromic acid)	$C_{64}H_{128}O_2$	——	

All the acids of the series containing up to nine atoms of carbon are volatile; the others are no longer so without decomposition, though they can be distilled in *vacuo*.

While formic and acetic acids are miscible in all proportions with water, the solubility in water of the other acids gradually decreases, and from oenanthylic acid down they are entirely insoluble in water.

Only monatomic acids occur in the natural fats, with the exception of sebacic acid in castor oil.

In close connection with the above fatty acids of the saturated hydrocarbons is a series of monatomic acids which contain two atoms less of hydrogen, being therefore derived from the non-saturated hydrocarbons and belonging to the oleic series with the general formula $C_nH_{n-2} + O_2$.

The alcohols of these acids have not yet been prepared, with the exception of allyl alcohol, C_3H_5OH.

$$\frac{C_3H_5OH}{\text{Allyl alcohol}} + \frac{O}{\text{Oxygen}} = \frac{HOH}{\text{Water}} + \frac{C_3H_4O{=}CH_2.CH.(COH)}{\text{Acrylaldehyde=acrolein.}}$$

$$\frac{C_3H_5OH}{\text{Allyl alcohol}} + \frac{2O}{\text{Oxygen}} = \frac{HOH}{\text{Water}} + \frac{C_2H_3.COOH}{\text{Acrylic acid.}}$$

By the absorption of two atoms of nascent hydrogen, most acids of the oleic acid group are converted into the corresponding fatty acids.

$$\frac{C_2H_3COOH}{\text{Acrylic acid}} + \frac{HH}{\text{Hydrogen}} = \frac{C_2H_5COOH}{\text{Propionic acid.}}$$

$$\frac{C_3H_5COOH}{\text{Crotonic acid}} + \frac{HH}{\text{Hydrogen}} = \frac{C_3H_7COOH}{\text{Butyric acid.}}$$

$$\frac{C_{17}H_{33}COOH}{\text{Oleic acid}} + \frac{HH}{\text{Hydrogen}} = \frac{C_{17}H_{35}COOH}{\text{Stearic acid.}}$$

OLEIC ACID OR ACRYLIC ACID GROUP.

Monobasic Acids $C_nH_{2n-2} + O_2$.	Formula.	Boiling point. Fusing point.
Acrylic acid..............................	$C_3H_4O_2$	100° C.
Crotonic acid (in croton oil)	$C_4H_6O_2$	72° "
Angelic acid	$C_5H_8O_2$	44° "
Pyroterebic acid	$C_6H_{10}O_2$	210° "
Physetoleic acid (in train oils).............	$C_{16}H_{30}O_2$	30° "
Hypogæic acid (in peanut oil).............	$C_{16}H_{30}O_2$	34° "
Oleic acid	$C_{18}H_{34}O_2$	liquid.
Erucic acid (in rape oil, etc.)...............	$C_{22}H_{42}O_2$	33° C.

On other non-saturated hydrocarbons are dependent, according to the formula $C_nH_{2n-4}O_2$: *linoleic acid* — $C_{15}H_{27}COOH$ · and $C_nH_{2n-4}O_2$: *ricinoleic acid* — $C_{17}H_{33}COOH$.

The first acid contains various components—see linoleic acid.

The natural vegetable fats contain only fatty acids with even carbon-atoms, for instance, C_4; C_{16}; C_{18}, etc.

With the aid of the acids and alcohols it is now easy to form the compound ethers or esters.

A distinction has to be made between *simple ethers* which are derived from the alcohols by the substitution of an alcohol radical for the hydrogen of the hydroxyl group

$$\frac{C_2H_5OH}{\text{Ethyl alcohol}} + \frac{C_2H_5OH}{\text{Ethyl alcohol}} = \frac{HOH}{\text{Water}} = \frac{(C_2H_5)_2O}{\text{Ethyl ether,}}$$

and *compound ethers or esters,* which are also derived from the alcohols, but the hydrogen of the hydroxyl group is replaced by an acid radical—formyl CHO—acetyl C_2H_3O—etc.

For the formation of compound ethers only one atom of hydrogen is to be replaced by acid radicals in the monatomic alcohols, two in the diatomic, and three in the triatomic = glycerin.

$$\frac{C_2H_5Cl}{\text{Ethyl chloride}} + \frac{CH_3COONa}{\text{Sodium acetate}} = \frac{NaCl}{\text{Sodium chloride}} + \frac{(CH_3COO).C_2H_5}{\text{Ethyl acetate or acetic ether.}}$$

$$\frac{C_2H_5Cl}{\text{Ethyl chloride}} + \frac{C_{15}H_{31}COONa}{\text{Sodium palmitate}} = \frac{NaCl}{\text{Sodium chloride}} + \frac{(C_{15}H_{31}COO).C_2H_5}{\text{Ethyl palmitate.}}$$

$$\frac{C_{16}H_{33}Cl}{\text{Cetyl chloride}} + \frac{C_{15}H_{31}COONa}{\text{Sodium palmitate}} = \frac{NaCl}{\text{Sodium chloride}} + \frac{(C_{15}H_{31}COO).C_{16}H_{33}}{\text{Cetyl palmitate = Spermaceti.}}$$

$$\frac{C_2H_4''Cl_2}{\text{Ethene dichloride}} + \frac{CH_3COOK}{\text{Potassium acetate}} + \frac{HOH}{\text{Water}} = \frac{HCl}{\text{Hydrochloric acid}} + \frac{KCl}{\text{Potassium chloride}} + \frac{C_2H_4''(CH_3COO)OH}{\text{Ethene monacetate.}}$$

$$\frac{C_2H_4''I_2}{\text{Ethene diodide}} + \frac{2CH_3COOAg}{\text{Silver acetate}} = \frac{2AgI}{\text{Silver iodide}} + \frac{(CH_3COO)_2.C_2H_4''}{\text{Ethene diacetate.}}$$

$$\frac{C_2H_5'''Br3}{\text{Tribromallyl}} + \frac{CH_3COOK}{\text{Potassium acetate}} + \frac{HOH}{\text{Water}} = \frac{2KBr}{\text{Potassium bromide}} + \frac{HBr}{\text{Hydrobromic acid}} + \frac{C_3H_5'''(CH_3COO)_2(OH)}{\text{Diacetin}} = \frac{C_3H_5'''Br_3}{\text{Tribromallyl}} + \frac{3CH_3COOAg}{\text{Silver acetate}} =$$

$$+ \underset{\text{Argentic bromide}}{\underline{\mathrm{3AgBr}}} + \underset{\text{Triacetin, in the oil of the seeds of the spindle tree (\textit{Evonymus europaeus}).}}{\underline{\mathrm{(CH_3COO)_3.C_3H_5'''}}}$$

$$\underset{\text{Tribromallyl}}{\underline{\mathrm{C_3H_5'''Br_3}}} + \underset{\text{Sodium stearate}}{\underline{\mathrm{C_{17}H_{35}COONa}}} + \underset{\text{Water}}{\underline{\mathrm{2HOH}}} = \underset{\text{Sodium bromide}}{\underline{\mathrm{NaBr}}} + \underset{\text{Hydrobromic acid}}{\underline{\mathrm{2HBr}}} + \underset{\text{Monostearin.}}{\underline{\mathrm{C_3H_5'''.(C_{17}H_{35}COO).OH_2}}}$$

$$\underset{\text{Tribromallyl}}{\underline{\mathrm{C_3H_5'''Br_3}}} + \underset{\text{Sodium stearate}}{\underline{\mathrm{2C_{17}H_{35}COONa}}} + \underset{\text{Water}}{\underline{\mathrm{HOH}}} = \underset{\text{Sodium bromide}}{\underline{\mathrm{2NaBr}}} + \underset{\text{Hydrobromic acid}}{\underline{\mathrm{HBr}}} + \underset{\text{Distearin, occurs in colza oil stearin.}}{\underline{\mathrm{(C_3H_5'''(C_{17}H_{35}COO)_2OH)}}}$$

$$\underset{\text{Tribromallyl}}{\underline{\mathrm{C_3H_5'''Br_3}}} + \underset{\text{Sodium stearate}}{\underline{\mathrm{3C_{17}H_{35}COONa}}} = \underset{\text{Sodium bromide}}{\underline{\mathrm{3NaBr}}} + \underset{\text{Tristearin.}}{\underline{\mathrm{(C_{17}H_{35}COO)_3.C_3H_5'''}}}$$

The formation of the monoglycerides, diglycerides, and triglycerides takes place also by direct contact of the components, slowly at an ordinary temperature, but more rapidly in closed glass tubes at a higher temperature. By bringing together one atom of palmitic acid and one atom of glycerin, one atom of water is eliminated and *monopalmitin* produced; with two atoms of palmitic acid, one atom of glycerin, and the elimination of two atoms of water, *dipalmitin*, and with three atoms of palmitic acid, one atom of glycerin, and the elimination of three atoms of water, *tripalmitin*. Or by heating glycerin and stearic acid to 392° F. for thirty-six hours, *monostearin* is formed; by heating the latter with three parts stearic acid to 500° F. for three hours, *distearin*, and finally by heating the latter with ten times the quantity of stearic acid, *tristearin*.

As plainly seen from the foregoing, fats may be formed artificially, such fats possessing the same properties as those occurring in nature.

The simple ethers are not attacked by alkalies, but the compound ethers split into acid, which remains fixed on the alkali and the proper alcohol.

$$\underset{\text{Acetic ether}}{\underline{\mathrm{C_2H_3O.O.C_2H_5}}} + \underset{\text{Sodium hydroxide}}{\underline{\mathrm{NaOH}}} = \underset{\text{Sodium acetate}}{\underline{\mathrm{CH_3.COONa}}} + \underset{\text{Alcohol.}}{\underline{\mathrm{C_2H_5OH}}}$$

$$\underset{\text{Ethene diacetate}}{\underline{\mathrm{(CH_3COO)_2.C_2H_4''}}} + \underset{\text{Sodium hydrate}}{\underline{\mathrm{2NaOH}}} = \underset{\text{Sodium acetate}}{\underline{\mathrm{2CH_3COONa}}} + \underset{\text{Glycol.}}{\underline{\mathrm{C_2H_4''(OH)_2}}}$$

$$\frac{(C_{17}H_{35}COO)_3C_3H_5''''}{\text{Tristearin}} + \frac{NaOH}{\text{Sodium hydroxide}} + \frac{2HOH}{\text{Water}} + \frac{C_{17}H_{35}COONa}{\text{Sodium stearate}} + \frac{C_3H_5''''.(C_{17}H_{35}COO)_2(OH)}{\text{Distearin.}}$$

$$\frac{(C_{17}H_{35}COO)C_3H_5}{\text{Tristearin}} + \frac{2NaOH}{\text{Sodium hydrate}} + \frac{HOH}{\text{Water}} + \frac{2C_{17}H_{35}COONa}{\text{Sodium stearate}} + \frac{C_3H_5''''.(C_{17}H_{35}COO).(OH)_2}{\text{Monostearin.}}$$

$$\frac{(C_{17}H_{35}COO)_3.C_3H_5'''}{\text{Tristearin}} + \frac{3NaOH}{\text{Sodium hydroxide}} = \frac{3C_{37}H_{35}COONa}{\text{Sodium stearate}} + \frac{C_3H_5'''.(OH)_3}{\text{Glycerin.}}$$

The natural ethers of the fatty acids, hence, the triglycerides, *i. e.*, glycerin, in which the three typical atoms of hydrogen have been replaced by univalent acid radicals, are indicated according to their acids as follows:

Butyrin	$C_{15}H_{26}O_6$,	fluid, boils at	285°	C.
Laurin	$C_{39}H_{74}O_6$,	fuses at	45°	"
Myristin	$C_{45}H_{86}O_6$,	"	55°	"
Palmitin	$C_{51}H_{91}O_6$,	"	62°	"
Stearin	$C_{57}H_{110}O_6$,	"	71.5°	"
Olein	$C_{57}H_{104}O_6$,	fluid, solid at	6°	"

The last three mentioned triglycerides are the bases of the fats and oils, and on the preponderance of one or the other depends the consistency, thus: oil, butter, grease, tallow. In the drying oils occurs more or less linoleic acid as *linolein*, and in train oils physetoleic acid as *physetolein*.

Diglycerides are found in various oils, especially in oils of the cruciferous plants, for instance *dicrucin* $C_3H_5'''(C_{21}H_{41}COO_2)$-(OH), in rape oil.

Oils in a fresh state, as well as animal fats, may be considered pure triglycerides, while, on the other hand, vegetable fats frequently contain, while still in the seed and consequently also after being obtained, free fatty acids, for instance:

Bassia fat,
Cocoanut oil,
Crabwood oil,
Dika fat,
Fulwa butter,
Galam butter,
Goa butter,
Japanese wax,
Laurel butter,
Maheva butter,
Palm oil,
Palm kernel oil,
Piney tallow,
Rambutan tallow,
Virola tallow.

In the ethers of the waxes occur the univalent alcohols of the formula: $C_nH_{2n+2}O$:

Cetyl alcohol	$C_{16}H_{34}O$,	fusing point,	49° C.
Stearyl alcohol	$C_{18}H_{38}O$,	"	59° C.
Ceryl alcohol	$C_{27}H_{56}O$,	"	79° C.
Myricyl alcohol	$C_{30}H_{62}O$,	"	85° C.

and of the aromatic series:

Cholesterin $C_{26}H_{41}O$ fuses at 145° C. Isocholesterin and phytosterin. $C_{27}H_{45}OH$

II. Decomposition of Fats by Alkalies.

As previously mentioned, the decomposition (saponification) of a fat by an alkali does not take place suddenly, but runs through various phases, and from what has been said it is evident that diglycerides must first be formed, next monoglycerides, which finally also succumb to the action of the alkali and are converted into neutral stearates—*soap*.

In no case are the fats and oils simple glycerides; for instance, stearin or olein, but always mixtures of glycerides, and they may be best designated by the general formula:

$$\begin{cases} \text{Stearate } (C_{17}H_{36}COO) \\ \text{Palmitate } (C_{15}H_{30}COO) \\ \text{Oleate } (C_{17}H_{33}COO) \\ \text{Glyceryl ether } C_3H_5{'''}. \end{cases}$$

The glycerides are not uniformly attacked by the alkalies, stearin and palmitin, being, for instance, more readily saponifiable than olein, because on slightly heating olive oil with soda lye the first two are saponified before the olein is attacked. This behavior presents a method for separating olein from palmitin and stearin.

The combinations of the fatty acids with metals of the alkalies, potassium and sodium, yield soaps soluble in water. In a finished state these soaps are distinguished one from another by their consistency, the potassium combinations being always softer than the sodium combinations.

The alkaline stearates are completely soluble in water and alcohol, and form with them foaming fluids; they are insoluble in ether, benzol, chloroform. Concentrated soap solutions, aqueous as well as alcoholic, gelatinize on cooling. Solution of soap diluted with much water is decomposed to free alkaline hydrate and acid alkaline stearate, the latter separating in small nacreous laminæ. To this property is due the detergent action of soap. The alkali removes the impurities, while the acid stearate dissolves the grease, both having a cleansing effect upon the skin as well as upon the clothes.

If a piece of soap wrapped up in gauze or muslin is partially placed in water, a clear fluid containing the sodium oleate is lixiviated, while the sodium stearate and palmitate, which dissolve with greater difficulty, remain standing as a coherent skeleton in the original shape of the piece of soap. Hence instead of a split into free alkali and acid alkaline stearate, the decomposition of soap with much water may perhaps be more correctly considered simply a separation of the more readily soluble sodium oleate from the sodium palmitate and stearate, dissolving with difficulty, because under ordinary conditions the sodium oleate exerts a solvent effect upon the other two combinations. It is also possible that an acid and a basic alkaline stearate are formed. The alkaline stearates are insoluble in pure common salt solution, and a potash soap is converted by common salt into a soda soap because the chlorine has greater affinity for potash.

Besides the sulphides of the alkalies, calcium and barium hydrate as well as lead oxide possess the ability of decomposing fats in the same manner as potassium hydrate and sodium hydrate, the soaps formed being, however, insoluble in water.

By fusing with potassium hydrate *oleic acid* = *acetopalmitic acid*, *erucic acid* = *acetoarachic acid*, *hypogaeic acid* = *acetomyristic acid*, and bodies isomeric with them, are decomposed to *palmitic acid*, *arachic acid*, *myristic acid* and *acetic acid*.

The action of *ammonia*, H_3N, upon the fixed oils differs from that of the other alkalies and metallic bases. If the emulsion obtained by agitating ammonia water with an oil be exposed to the air, the volatile alkali is after some time completely dissipated, and the oil remains behind in its original state. This shows that ammonia does not possess the power of saponifying fats.

By *alcoholic ammonia solution* the fats after being for some time exposed to the cold are however decomposed to *acetamides*, for instance, *palmitamide* = $C_{16}H_{31}O.H_2N$, etc., and to glycerin.

Organic combinations derived from ammonia and the hypothetical ammonium hydroxyl, NH_4OH, are, however, capable of saponifying fats and oils; they are *tetramethyl-ammonium hydroxide* and homologous combinations.

$$\underbrace{H_3N}_{\text{Ammonia}}, \quad \underbrace{(CH_3)_3N}_{\text{Trimethylamine}}, \quad \underbrace{(NH_4)OH}_{\text{Ammonium hydroxide}}, \quad \underbrace{N(CH_3)_4OH}_{\text{Tetramethyl-ammonium hydroxide.}}$$

If a soap solution is mixed with a lime salt solution a white precipitate of calcium stearate is formed, which proves that water rich in lime salts cannot be used for washing. The various alkaline soaps are decomposed by free acid, for instance, sulphuric acid, hydrochloric acid, the stronger acid fixing the base, while the fatty acid separates.

III. Decomposition of Fats by Heating.

Fats possess the characteristic property of decomposing when strongly heated, and yielding thereby sharp, acrid acrolein vapors of a disagreeable odor.

Acrolein = *acrylic aldehyde*, C_3H_4O, is formed, as above mentioned, when fats are strongly heated or subjected to destructive distillation, chiefly in consequence of the decomposition of the glycerin, water being at the same time separated.

$$\underbrace{C_3H_5'''(OH)_3}_{\text{Glycerin}} = \underbrace{2HOH}_{\text{Water}} + \underbrace{C_3H_4O}_{\text{Acrolein.}}$$

This body is derived from a univalent allyl acohol, C_3H_6O, in the same manner as mentioned on p. 109. It is easily obtained by depriving glycerin of the elements of water, which is best effected by heating glycerin with acid potassium sulphate or phosphorus pentoxide. It is a clear colorless liquid, specifically lighter than water, and boils at 52° C. Its vapor is very irritating, attacking most violently the mucous membranes of the nose and eyes. By the absorption of oxygen the acrolein is converted into acrylic acid, C_3H_4O, homologous with oleic acid.

By passing fat drop by drop through an iron pipe at a slight red heat, the fat yields but few liquid products of decomposition, but is almost entirely converted into a gas mixture—*oil-gas*—which of all gases used for illuminating purposes, evolves most light.

Oil gas is a mixture of carbon dioxide, hydrogen gas, olefiant gas, benzine, etc.

When fats are subjected to destructive distillation hydrocarbons are formed, and a tarry mass, which under the name of *oleum philosophorum* is used in veterinary science.

IV. ACTION OF ACIDS UPON FATS AND FATTY ACIDS.

(*Sulphuric, Hydrochloric, Nitric Acids.*)

Dilute cold or warm sulphuric acid does not attack fats and oils, but *concentrated sulphuric* acid in excess decomposes them, sulphurous acid, $H_2SO_4—O$, being constantly evolved. If 8 to 19 per cent. of sulphuric acid of 66° Bé. is allowed to act for some time in the cold, or only a few minutes at about 230° F., so-called *sulpho-acids* or Fremy's acids are formed, which are combinations of the fatty acids as well as of the glycerin with sulphuric acid.

$$\underset{\text{Olein}}{\underline{(C_{17}H_{14}COO)_3C_3H_5'''}} + 6H_2SO_4 = \underset{\text{Sulpho-stearic acid}}{\underline{3C_{17}H_{34}.SO_4H.COOH}} + \underset{\text{Sulpho-glyceric acid.}}{\underline{C_3H_5'''(SO_4H).OH_2}}$$

In treating these sulpho-acids with boiling water the sulpho-glyceric acid undergoes complete splitting, while the sulpho-palmitic and sulpho-stearic acids absorb hydroxyl.

$$\underset{\text{Sulpho-glyceric acid}}{\underline{C_3H_5'''(SO_4H).OH_2}} + HOH = \underset{\text{Sulphuric acid}}{\underline{SO_4H_2}} + \underset{\text{Glycerin.}}{C_3H_5'''OH_3}$$

$$\underset{\text{Sulpho-stearic acid}}{C_{37}H_{34}.SO_4H.COOH} + HOH = SO_4H_2 + \underset{\text{Oxystearic acid.}}{C_{37}H_{34}.(OH).COOH}$$

Sulphuric acid and glycerin dissolve in water, while the oxy-fatty acids remain undissolved.

Besides oxystearic acid there are formed at the same time small quantities of *oxystearo-sulphuric acid*, $C_{18}H_{34}O_2$, which forms white laminae fusing at 116.6° to 118.4° F., and is soluble with difficulty in alcohol. The white crystals of the oxystearic acid fuse at 177.8 to 178.7° F., and are readily soluble in alcohol and ether.

Upon these operations is based the hardening of tallow with sulphuric acid, the oleic acid being thereby converted into oxystearic acid.

Hydrochloric acid has scarcely any effect, under heat, and none in the cold.

Nitric acid, dilute and cold, is without effect; the concentrated acid decomposes the fats under heat, and finally yields oxalic, succinic and adipic acids.

Nitrous acid exhibits a peculiar action upon oils containing oleic acid, it converting the fluid olein into the solid isomeric *elaïdin*, or the oleic acid into *elaïdic acid*. Of the fatty acids of the non-saturated hydrocarbons—$C_nH_{2n-2}O_2$,—those mentioned below are also converted into isomeric combinations:

			Fusing point.
Hypogæic acid	into	Gaïdic acid	102.2° F.
Oleic acid	"	Elaïdic acid	111.2° F.
Erucic acid	"	Brassaïdic acid	132.8° F.

Further

Ricinoleic acid	into	Ricinelaïdic acid	122° F.

Oils containing the groups of linoleic acid, *i. e.*, drying oils, are not acted upon by nitrous acid.

V. Decomposition of Fats by Water.

All fats when heated with water in a hermetically closed tube to 428° F. are decomposed to glycerin and hydrated stearate.

$$\underbrace{(C_{37}H_{35}COO)_3C_3H_5'''}_{\text{Tristearin}} + \underbrace{3HOH}_{\text{Water}} = \underbrace{3C_{37}H_{35}COOH}_{\text{Stearic acid}} = \underbrace{C_3H_5'''(OH)_3}_{\text{Glycerin.}}$$

This behavior explains the action of superheated steam under strong pressure (10 to 12 atmospheres) upon the natural fats, of which practical use is made in the manufacture on a large scale of fatty acids and glycerin.

CHAPTER VI.

PROXIMATE CONSTITUENTS OF FATS AND OILS.

I. GLYCERIN — ALCOHOLS — CHOLESTERIN — GLYCERIDES— FATTY ACIDS.

1. *Glycerin or propenyl alcohol,* $C_3H_5'''(OH)_3 = CH_2—(OH).$-$CH—(OH).CH_2—(OH)$.

	Atomic weight.	Specific gravity 2.80.
3C	36	39.03 per cent.
8H	8	8.76 "
3O	48	52.21 "
1 molecule $C_3H_8O_3$	92	100.00 per cent.

Glycerin—*principium dulce oleorum*—was discovered in 1778 by Scheele whilst engaged in preparing lead plaster; it was further investigated by Chevreul, Pelouze and Bertholet. It is the triatomic alcohol of the group of fatty bodies and a derivative of the hydrocarbon *propane*, C_3H_8, in which three atoms of hydrogen are replaced by hydroxyl.

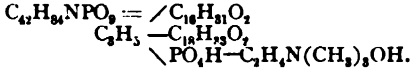
$$\underset{\text{Propane}}{\underline{C_3H_5H_3}}; = \underset{\text{Glycerin.}}{\underline{C_3H_5'''(OH)_3}}$$

It is not found in a free state, but always in combination with fatty acids or oleic acid, and is separated from the fats by strong basic hydrates, or sulphuric acid, or steam, these methods being now used for its production on a large scale. It is also formed in small quantities as a product of the fermentation of sugar, and is therefore present in all fermented beverages, especially in wine and beer.

By long exposure to the air, especially in the presence of moisture, many fats suffer partial decomposition to free acid and glycerin, and become thereby rancid.

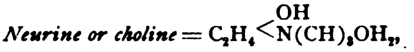
Glycerin combines with the elements of phosphoric acid, forming *glycerinphosphoric acid*, a complicated derivative of which, *lecithine* = *protagon* is found widely distributed in the animal organism, occurring in the brain, nerves, yolk of eggs, blood corpuscles, gall, etc.

Quite a number of seeds, for instance those of leguminous plants, *Aesculinæ*, etc., carry fats containing phosphorus in the form of lecithine =



$$C_{42}H_{84}NPO_9 = C_3H_5\begin{cases} C_{16}H_{31}O_2 \\ C_{18}H_{33}O_2 \\ PO_4H{-}C_2H_4N(CH_3)_3OH. \end{cases}$$

It is a waxy indistinctly crystalline mass, readily fusible, soluble in alcohol and ether; in water it swells up, softens and becomes gelatinous, but does not dissolve. On heating with acids or barium water, lecithine is resolved into



Neurine or choline = $C_2H_4{<}\begin{matrix} OH \\ N(CH)_3OH_2, \end{matrix}$

glycerinphosphoric acid = $C_3H_5(OH)_2PO_4H_2$,

and fatty acids—*palmitic, stearic and oleic acids.*

Ordinarily glycerin is a colorless, inodorous, syrupy liquid, very sweet and somewhat warm to the taste, owing to its affinity for water, oily to the touch, without action upon litmus, and soluble in all proportions in water and alcohol; also in spirit of ether, but not in ether, chloroform, benzol, fixed oils or volatile oils. When quickly cooled it does not crystallize, and even at —40° F. solidifies only to a gummy mass. By exposure for a long time—weeks—to a temperature of 32° F. it forms rhombic crystals resembling rock-candy. The crystals are very deliquescent, and melt at 62.6° F.

The boiling point of glycerin, under ordinary atmospheric pressure, is 554° F. When anhydrous it takes fire at 302° F., and burns quietly with a blue, non-luminous flame without giving off any disagreeable odor, and without leaving any residue. At about 212° F. it volatilizes in appreciable quantity, but more readily with the vapors of water, a circumstance which has to be taken into consideration in making determinations.

Glycerin is very hygroscopic, it absorbing up to 50 per cent. of moisture. In mixing it with snow or ice a decrease in the temperature to 14° F. takes place. In the presence of free alkali it rapidly absorbs ozone, producing thereby carbonic acid, formic acid, propionic acid, and an acrolein odor. Acrolein is also formed by substances withdrawing water.

Glycerin dissolves all deliquescent salts; and it is also a solvent for many organic and inorganic compounds which are soluble in water or alcohol, and prevents the precipitation of some salts by alkalies and other reagents.

In the same manner as by the substitution of acid radicals for hydrogen in glycerin, compound ethers—*glycerides*—are formed, the hydrogen may also be replaced by metals, for instance, sodium, etc., and *glycerates* be formed, for example:

$$C_3H_5'''(OH)_2.ONa = \text{monosodium glycerate,}$$
$$C_3H_5'''(OH)(ONa)_2 = \text{disodium glycerate,}$$
$$C_3H_5'''(ONa)_3 = \text{trisodium glycerate.}$$

By alkali in a fusing state glycerin is resolved into *potassium acetate* and *potassium formate*, hydrogen being evolved:

$$\frac{C_3H_5(OH_3)}{\text{Glycerin}} + \frac{2\ KOH}{\text{Potassium hydroxide}} = \frac{H.COOK}{\text{Potassium formate}} + \frac{CH_3COOK}{\text{Potassium acetate}} + (HOH)_2 + 4H.$$

In the distillation of glycerin with calcium chloride there is formed, besides phenol, $C_6H_5.OH$, *glyceric ether*, $(C_3H_5)_2O_3$, a fluid boiling at 341.6° F.

In the presence of certain bacteria, glycerin passes into fermentation; thus *Bacillus subtilis* produces chiefly ethyl alcohol and butyric acid, while another bacillus causes the formation of propyl alcohol, butyl alcohol and capronic acid.

By moderate oxidation of dilute glycerin with nitric acid at an ordinary temperature, *glyceric acid* = *dioxypropionic acid* = $C_3H_6O_4 = CH_2(OH)—CH(OH)—COOH$ is formed, 2 atoms of hydrogen being eliminated and oxygen absorbed: with stronger oxidation *oxalic acid* = $C_2H_2O_4$ = COOH—COOH, is formed.

By the simultaneous treatment of glycerin with nitric and sulphuric acids, the three hydrogen atoms of glycerin are replaced by three radicals of nitric acid = nitroxyl = NO_2, and *propenyl nitrate*, commonly called *nitroglycerin*, is formed.

$$\underbrace{C_3H_5'''(OH)_3}_{\text{Glycerin}} + \underbrace{3NO_2H}_{\text{Nitric acid}} = \underbrace{3HOH}_{\text{Water}} + \underbrace{C_3H_5'''(O.NO_2)_3}_{\text{Nitroglycerin.}}$$

Nitroglycerin is a heavy, colorless, oily liquid, possessing a burning sweet taste and poisonous properties, the inhalation of the vapor producing severe headache. It is soluble with difficulty in water, but readily in alcohol and chloroform. It crystallizes at —4° F. It is a very dangerous compound, exploding on heating it or by percussion, with the utmost violence. It was formerly much employed for blasting in mines and quarries, but has been largely replaced by the compound known as *dynamite*, which consists of nitroglycerin mixed with finely-divided silica, so-called *Kieselguhr*, the remains of infusoria.

By the saturation of glycerin with hydrochloric acid the so-called *chlorhydrins* are obtained, according to the duration of the action of the acid:

Monochlorhydrin	$C_3H_7ClO_2$
Dichlorhydrin	$C_3H_6Cl_2O$
Trichlorhydrin	$C_3H_5Cl_3$.

Glycerin has become largely employed for technical and medicinal purpŏses, owing to its physical properties, its stability, its pleasant sweet taste when quite pure, its harmlessless, its great solvent power for many substances, and lastly to its low price.

Being a hygroscopic body, it is added to snuff, chewing tobacco, blacking, stamping inks, copying inks, etc., to prevent drying in.

Boiled with glue or gelatin, glycerin yields a mass used for printers' rollers, hektographs, etc.

In weaving it serves for the preparation of the dressing with dextrin and sulphate of alumina.

It is employed in dyeing, tanning and in the manufacture of paper; further, as a lubricant for watches and machines, and for the manufacture of artificial mustard oil. It is also employed for filling gas meters which fail to work in winter on account of the water freezing, and in summer in consequence of the evaporation of water; an addition of glycerin removing both evils.

Glycerin renders the skin soft, and is therefore employed in the manufacture of cosmetics, for instance toilet soaps, toilet waters, etc. It is serviceable in burns and catarrhal affections, and may be advantageously administered in large doses to persons suffering from *diabetes mellitus.*

2. *Monohydric alcohols or carbinols.*

a. *Cetyl alcohol* also called *ethal* = $C_{16}H_{34}O$ = $C_{15}H_{31}.CH_2OH$, is the principal constituent of spermaceti. To prepare it, spermaceti is boiled with alcoholic potash solution, whereby it is resolved into potassium palmitate and cetyl alcohol. The latter is dissolved out from the fused mass by alcohol and ether, and purified by several crystallizations from ether.

Cetyl alcohol forms white lustrous laminæ without odor or taste, which fuse at 121.5° F., and boil almost without decomposition at about 752° F. By oxidation cetyl alcohol is converted into *palmitic aldehyde*, $C_{15}H_{31}.COH$, and *palmitic acid*, $C_{15}H_{31}.COOH$.

By fusing cetyl alcohol with soda-lime, sodium palmitate is formed, hydrogen being evolved.

$$\frac{C_{15}H_{31}.CH_2OH}{\text{Cetyl alcohol}} + NaOH = 4H + \frac{C_{15}H_{31}.COONa}{\text{Sodium palmitate.}}$$

b. *Ceryl alcohol or cerotic alcohol* = $C_{27}H_{56}O$ = $C_{26}H_{53}CH_2OH$. This alcohol is obtained from Chinese wax, which consists almost entirely of *ceryl cerotate*, $C_{26}H_{53}.COOC_{27}H_{55}$, by saponifying the wax with caustic potash and adding barium chloride. The resulting mixture of ceryl alcohol and barium cerotate is precipitated and may be separated by exhausting the dry precipitate with hot alcohol, in which the barium salt is insoluble. Ceryl alcohol is a waxy mass fusing at 174.2° F.

c. *Myricyl alcohol* = $C_{30}H_{62}O$ = $C_{29}H_{59}.CH_2OH$ occurs in some varieties of wax, bees' wax, Carnauba wax. It is obtained from *myricin*, the portion of bees' wax which is insoluble in boiling alcohol. Myricin consists of *myricyl palmitate* and, when heated with potash, is decomposed in the same manner as spermaceti and Chinese wax, yielding potassium palmitate and myricyl alcohol. Myricyl alcohol forms white silky acicular crystals, insoluble in water and dissolving with difficulty in alcohol; they fuse at 185° F.

Determination of glycerin and of cetyl, ceryl and myricyl alcohols. The *qualitative* determination of glycerin is effected, according to Reichelt, as follows: Heat two drops of glycerin with two drops of fused phenol and the same quantity of sulphuric acid to about 248° F.; after cooling, the brown solid mass formed dissolves in ammonia with a beautiful carmine-red color.

The *quantitative* determination of the content of glycerin in a fat or oil was formerly executed by saponifying the fat, etc., decomposing the soap formed by acid, evaporating the acid fluid to dryness, and extracting the residue with alcohol. After evaporating the alcoholic solution the glycerin remained behind. However, since glycerin was carried away with the vapors, the results were inaccurate. The determination has been simplified by Zulkowsky's saponifying method, it being no matter whether a neutral fat has to be examined, or a fat containing free fatty acids. In the latter case the fatty acids are first determined with standard alkali, and then the remaining neutral fats saponified. Three molecules caustic potash (168) correspond to one molecule glycerin (92). See "Saponification Number" later on.

By the oxidation of glycerin in strong alkaline solution, at an ordinary temperature, with potassium permanganate, one molecule glycerin yields quantitatively exactly one molecule each of oxalic and carbonic acids:

$$C_3H_8O_3 + 3O_2 = C_2H_2O_4 + CO_2 + 3H_2O.$$

Upon this principle, first stated by Fox, is based Benedikt and Zsigmondy's [*] method of determining glycerin. It is executed as follows: Two or three grammes of fat are saponified with caustic potash and perfectly pure methyl alcohol. The alcohol is then driven off by evaporation, the residue dissolved in hot water, and the soap decomposed with dilute hydrochloric acid. It is then heated until the fatty acids have separated clear. With fluid fats it is recommended to add some hard paraffin to assist the solidification of the fatty acids floating on the surface in cooling, the latter being effected by placing the dish in cold water. The whole is then filtered and washed into a capacious flask, neutralized, after the addition of one drop of phenolphthalein, with caustic potash, and about ten grammes more of caustic potash added. Enough of five per cent. potassium permanganate solution is then added to render the fluid no longer green, but blue or blackish. Finely-powdered potassium permanganate may be used instead of solution of the salt. The whole is then heated to boiling, whereby hydrated manganese dioxide separates, and the liquid becomes red. Enough aqueous sulphurous acid is then added to produce decolorization, whereby the liquid must remain strongly alkaline. The whole is now filtered through a smooth filter of sufficient capacity to hold one-half of the liquid at one time, and thoroughly washed with boiling water. The last wash-waters are frequently rendered turbid by manganese dioxide. This turbidity, however, disappears by acidulation with acetic acid, the sulphurous acid liberated thereby becoming active. As a rule 600 to 1000 cubic centimeters of liquid are obtained, which are heated almost to boiling, and precipitated with a 10 to 12 per cent. solution of calcium chloride or acetate. With a larger addition of calcium considerable quantities of gypsum are precipitated, which renders the determination inaccurate. Besides calcium oxalate, the precipitate always contains silica. Hence after igniting it cannot be designated pure calcium carbonate or calcium oxide, and the determination of the calcium oxalate contained therein is best effected by titration either with potassium permanganate in acid solution or, after igniting, by alkalimetry. In the latter case the precipitate is ignited, dissolved in semi-normal hydrochloric acid, and back-titrated with semi-normal alkali, using methyl orange as indicator. The hydrochloric acid is generally standardized for sodium carbonate: 106 parts sodium carbonate corresponding to 92 parts glycerin. The presence of volatile fatty acids has no disturbing influence upon the determination.

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[*] Chemiker Zeitung, 9.975.

V. Planchon's method allows of rapid execution and yields very good results. It is based upon the principle that by oxidation of glycerin in acid solution with potassium permangate the glycerin is oxidized to carbonic acid and water:

$$C_3H_5(OH)_3 + 7O = 3CO_2 + 4H_2O.$$

The process of determination is as follows: 5 grammes of oil or fat which contain about 0.5 gramme glycerin are saponified, the soap formed is decomposed with 10 cubic centimeters of 15 per cent. sulphuric acid, the fatty acids taken off and the fluid containing the glycerin brought into a flask and augmented to 200 cubic centimeters. The flask is previously so arranged that the carbonic acid evolved is dried in calcium chloride tubes and absorbed in weighed soda-lime tubes. 4.2 grammes of powdered potassium permanganate are then brought into the flask and the fluid heated. 33 parts carbonic acid correspond to 23 parts glycerin.

David's method. For determining the glycerin in fats, etc. 100 grammes of fat are heated with 65 grammes crystallized barium hydrate and 80 cubic centimeters of 95 per cent. alcohol added with constant stirring. By the escape of the alcohol the mixture soon becomes solid. It is then boiled with ½ liter of water, the fluid poured off after settling, and the barium residue twice lixiviated. The wash-water is united with the principal solution, evaporated to one-half the quantity with sulphuric acid, and the free acid removed with barium carbonate. The solution is filtered and the filtrate evaporated to 50 cubic centimeters. In the latter the quantity of glycerin can be determined by the specific gravity, or by refraction.

SPECIFIC GRAVITIES AND REFRACTIVE INDICES OF AQUEOUS GLYCERIN SOLUTIONS (*According to Skalweit*).

Per cent. Glycerin.	Specific Gravity at 59° F.	Refractive Index for D at 59° F.	Per cent. Glycerin.	Specific Gravity at 59° F.	Refractive Index for D at 59° F.	Per cent. Glycerin.	Specific Gravity at 59° F.	Refractive Index for D at 59° F.
0	1.0000	1.3330	34	1.0858	1.3771	68	1.1799	1.4265
1	1.0024	1.3342	35	1.0885	1.3785	69	1.1827	1.4280
2	1.0048	1.3354	36	1.0912	1.3799	70	1.1855	1.4295
3	1.0072	1.3366	37	1.0939	1.3813	71	1.1882	1.4309
4	1.0096	1.3378	38	1.0966	1.3827	72	1.1909	1.4324
5	1.0120	1.3390	39	1.0993	1.3840	73	1.1936	1.4339
6	1.0144	1.3402	40	1.1020	1.3854	74	1.1963	1.4354
7	1.0168	1.3414	41	1.1047	1.3868	75	1.1990	1.4369
8	1.0192	1.3426	42	1.1074	1.3882	76	1.2017	1.4384
9	1.0216	1.3439	43	1.1101	1.3896	77	1.2044	1.4399
10	1.0240	1.3452	44	1.1128	1.3910	78	1.2071	1.4414
11	1.0265	1.3464	45	1.1155	1.3924	79	1.2098	1.4429
12	1.0290	1.3477	46	1.1182	1.3938	80	1.2125	1.4444
13	1.0315	1.3490	47	1.1209	1.3952	81	1.2152	1.4460
14	1.0340	1.3503	48	1.1236	1.3966	82	1.2179	1.4475
15	1.0365	1.3516	49	1.1263	1.3981	83	1.2206	1.4490
16	1.0390	1.3529	50	1.1290	1.3996	84	1.2233	1.4505
17	1.0415	1.3542	51	1.1318	1.4010	85	1.2260	1.4520
18	1.0440	1.3555	52	1.1346	1.4024	86	1.2287	1.4535
19	1.0465	1.3568	53	1.1374	1.4039	87	1.2314	1.4550
20	1.0490	1.3581	54	1.1402	1.4054	88	1.2341	1.4565
21	1.0516	1.3594	55	1.1430	1.4069	89	1.2368	1.4580
22	1.0542	1.3607	56	1.1458	1.4084	90	1.2395	1.4595
23	1.0568	1.3620	57	1.1486	1.4099	91	1.2421	1.4610
24	1.0594	1.3633	58	1.1514	1.4104	92	1.2447	1.4625
25	1.0620	1.3647	59	1.1542	1.4129	93	1.2473	1.4640
26	1.0646	1.3660	60	1.1570	1.4144	94	1.2499	1.4655
27	1.0672	1.3674	61	1.1599	1.4160	95	1.2525	1.4670
28	1.0698	1.3687	62	1.1628	1.4175	96	1.2550	1.4684
29	1.0724	1.3701	63	1.1657	1.4190	97	1.2575	1.4698
30	1.0750	1.3715	64	1.1686	1.4205	98	1.2600	1.4712
31	1.0777	1.3729	65	1.1715	1.4220	99	1.2625	1.4728
32	1.0804	1.3743	66	1.1743	1.4235	100	1.2650	1.4742
33	1.0831	1.3757	67	1.1771	1.4250			

The above table, of course, gives accurate results only at the temperature indicated, since the refractive index changes with the temperature. Van der Willingen, for instance, found the following variations in the refractive indices for each degree C. increase in the temperature:

Specific gravity of glycerin.	Variation in the refractive index.
1.24049	0.00025
1.19286	0.00023
1.16270	0.00022
1.11463	0.00021
1.2535	0.00032

For pure water the variation is 0.00008 for 1° C.

Lenz has proposed the following method, which makes the determinations of the refractometer independent of the small variations in adjusting the index, and considerably decreases the influence of the temperature. The refraction of the respective solution is observed, and directly afterwards, at the same temperature, the refraction of pure water. The differences, with the per cent. content of the solutions in pure glycerin belonging to them, are found in the following table:

TABLE SHOWING THE DIFFERENCES BETWEEN THE REFRACTIVE INDICES OF AQUEOUS GLYCERIN SOLUTIONS AND PURE WATER (*According to Lenz*).

Dn* Glycerin—Dn Water.	Weight per cent. glycerin.	Dn Glycerin—Dn Water.	Weight per cent. Glycerin.	Dn Glycerin—Dn Water.	Weight per cent. Glycerin.	Dn Glycerin—Dn Water.	Weight per cent. Glycerin.
0.1424	100	0.1061	75	0.0673	50	0.0318	25
0.1410	99	0.1046	74	0.0659	49	0.0305	24
0.1395	98	0.1032	73	0.0645	48	0.0292	23
0.1381	97	0.1018	72	0.0630	47	0.0278	22
0.1366	96	0.1003	71	0.0616	46	0.0265	21
0.1352	95	0.0987	70	0.0601	45	0.0251	20
0.1337	94	0.0970	69	0.0587	44	0.0238	19
0.1323	93	0.0952	68	0.0572	43	0.0225	18
0.1308	92	0.0933	67	0.0556	42	0.0212	17
0.1294	91	0.0915	66	0.0541	41	0.0199	16
0.1279	90	0.0897	65	0.0526	40	0.0186	15
0.1264	89	0.0879	64	0.0510	39	0.0173	14
0.1250	88	0.0861	63	0.0495	38	0.0160	13
0.1235	87	0.0842	62	0.0479	37	0.0146	12
0.1221	86	0.0824	61	0.0464	36	0.0133	11
0.1206	85	0.0806	60	0.0451	35	0.0120	10
0.1191	84	0.0792	59	0.0438	34	0.0108	9
0.1177	83	0.0780	58	0.0424	33	0.0096	8
0.1162	82	0.0768	57	0.0411	32	0.0083	7
0.1148	81	0.0757	56	0.0398	31	0.0071	6
0.1133	80	0.0745	55	0.0385	30	0.0058	5
0.1119	79	0.0731	54	0.0372	29	0.0046	4
0.1104	78	0.0717	53	0.0358	28	0.0033	3
0.1090	77	0.0702	52	0.0345	27	0.0021	2
0.1075	76	0.0688	51	0.0332	26	0.0008	1
						0.0000	0

* Dn is the refractive index (n) for the sodium line D, which is directly indicated by the refractometer.

Glycerin is the trivalent alcohol soluble in water, while the univalent alcohols occurring in the fats are insoluble; by sufficient dilution and very gradual cooling of the soap paste, the latter separate upon the surface or may be extracted with petroleum ether from the evaporated, or still better dried, soap paste. These separations—celyl, ceryl and myricyl alcohols and cholesterin—have to be purified after the evaporation of the ether by recrystallization from hot alcohol. They are distinguished from each other by their fusing points, p. 106, or if necessary are further decomposed by fractional congealing—fractional crystallization.

To distinguish the univalent alcohols they may also, according to Benedikt, be converted into acetic ethers and their saponification numbers, *acetyl number*, etc., which are sufficiently far apart, determined. For this purpose the non-saponifiable residues are boiled with an equal weight of acetic anhydride in a flask with reflux-cooler for 1 to 2 hours. After cooling, cetyl, ceryl and myricyl alcohols remain in solution, while cholesterin separates in pasty crystals. For determining the saponification number the contents of the flask are freed from acetic acid by repeated boiling with water, the acetic ethers recrystallized from alcohol, and decomposed with titrated $\frac{1}{10}$ potash lye.

The acetyl number is for

cetyl alcohol	197.5	myricyl alcohol	112.2
ceryl alcohol	128.1	cholesterin	135.5

4. *Cholesterin*—$C_{26}H_{44}O$—*Phytosterin.*

Cholesterin is a univalent alcohol of the aromatic group, which contains fixed 1 molecule water: $C_{26}H_{44}O + HOH$. It is a product of the animal organism, and is found in small quantity in the animal system, as in the bile, the brain and nerves, and the blood; it forms the chief ingredient of biliary calculi. It occurs also in fats, wool fat, etc., and is extracted from the latter by a process of saponification.

From alcohol it crystallizes in small brilliant plates without color, odor or taste, which are soluble in hot alcohol, ether, chloroform and glacial acetic acid, but insoluble in water. Cholesterin fuses at 293° F., and boils almost without decomposition at 680° F.

The *cholesterin*, or according to Hesse, *phytosterin* of plants is isomeric with the cholesterin of animals, an essential difference being in the form of the crystals; phytosterin crystallizes in fascicular needles, and cholesterin in rhombic plates. Besides cholesterin, wool fat contains isocholesterin.

The crystals of

phytosterin fuse at 269.6° to 271.4° F.
isocholesterin fuse at 278.6° to 280.2° F.
cholesterin fuse at 293° F.

Cholesterin and phytosterin turn the plane of polarization to the left, and isocholesterin to the right. The determination is executed as follows:

1. If to a solution of cholesterin or phytosterin in chloroform 2 cubic centimeters of concentrated sulphuric acid be added, the chloroform acquires first a blood-red color, and then a cherry-red to purple, while the sulphuric acid beneath it shows a greenish-yellow fluorescence. On evaporating the red chloroform solution, it acquires first a blue, then a green, and finally a greenish-yellow color.

2. By adding drop by drop acetic anhydride to a cold solution of cholesterin and phytosterin, the solution becomes first transiently rose color and then permanently blue. Isocholesterin also behaves indifferently.

For the quantitative determination of cholesterin, isocholesterin and phytosterin in fats and oils, train oils, etc., the substance to be examined is, according to E. Schulze, fused together, best in a closed-glass tube, with 4 parts benzoic acid or benzoic anhydride, whereby cholesterin benzoate and isocholesterin benzoate are formed.

The cholesterin ethers being almost insoluble in boiling alcohol, are by that means separated from the many admixtures. In ether the combinations are soluble and crystallize from it with slow evaporation, the cholesterin benzoate in characteristic rectangular lustrous plates, and alongside these plates the isocholesterin benzoate in a loose crystalline powder, which can be separated by washing.

Cholesterin benzoate fuses at 302 to 303.8° F.

Isocholesterin benzoate fuses at 374 to 375.8° F.

On heating with alcoholic potash solution, these combinations are rapidly decomposed, cholesterin or isocholesterin being reformed, when the above mentioned reactions can be made. The shape of the crystals and the fusing points serve for distinguishing the three isomeric substances. Regarding the content of non-saponifiable substances in fats nnd oils, see p. 103.

4. *Glycerides.*

Butyrin, $(C_4H_7O)_3.C_3H_5''' = (C_3H_7COOO)_3.C_3H_5'''$. Tributyrin is a constituent of cow butter. Artificially it is prepared by heating dibutyrin $(C_3H_7.COO)_2.OH.C_3H_5'''$ with 15 to 20 parts butyric acid, $C_3H_7.COOH$ to 464° F. It is a neutral oily liquid having a peculiar smell and an acrid taste; it is insoluble in water, but soluble in alcohol and ether. Its specific gravity is 1.056 at 46.5° F. Tributyrin treated in the cold with sulphuric or hydrochloric acid and alcohol is converted into butyric ether having a pleasant odor, and into glycerin.

Laurin $(C_{12}H_{23}O)_3.C_3H_5''' =$ laurostearin, occurs in the fruit of *Laurus nobilis*, in bay oil, in pichurim beans of *Nectandra Puchury*, in cocoanut oil, and very likely in other fats. It can be prepared by extraction with hot alcohol and frequent recrystallization. It is a pure white mass of loose texture, consisting of very small pearly needles frequently grouped in the form of a star. It is insoluble in water, difficult to dissolve in cold alcohol, but quite readily so at the boiling temperature. On cooling it is, however, almost completely reseparated.

It is readily saponified by potash lye, yielding a clear soap paste. It melts at 111° to 113° F., and solidifies to a stearin-like, brittle, friable mass. Heated to above its melting point, it is decomposed into acrolein and a solid fat body crystallizable from ether and alcohol.

Myristin $(C_{14}H_{27}O_3)_3.O_3.C_3H_5''' = (C_{13}H_{27}COO)_3.C_3H_5'''$, the glyceride of myristic acid, is a constituent of expressed oil of nutmegs, the fat of *Myristica moschata*. It occurs chiefly in the portion difficult to dissolve in alcohol, and can therefore be obtained from it in a pure state by recrystallization from boiling ether. It is a pearly crystalline fat, soluble in all proportions in hot ether, but less so in hot alcohol, and entirely insoluble in water. It fuses at 88° F. Caustic alkalies and lead vinegar resolve it into glycerin and myristic acid.

Palmitin, $(C_{16}H_{31}O)_3.O_3.C_3H_5''' = (C_{15}H_{31}COO)C_3H_5'''$.

	Atomic weight.	
51C	612	75.93 per cent.
98H	98	12.16 "
6O	96	11.91 "
1 molecule $C_{51}H_{98}O_6$	806	100.00

Palmitin = *tripalmitin* forms, besides tristearin and olein, the principal constituent of most natural fats. It is prepared from palm oil, from the portion of olive oil solidifying on cooling, from Chinese tallow of *Stillingia sebifera*, or from the wax of *Myrica cerifera*.

To prepare it, palm oil is subjected to strong pressure between linen to remove liquid triolein. The residue is treated six to seven times with boiling alcohol to dissolve free oleic acid and palmitic acid. The residue consists of palmitin, and is several times recrystallized from ether. Or the melted tallow of *Stillingia sebifera* is treated with ether, then strongly pressed, and the operation repeated several times with the press-cake. The palmitin is then crystallized from the ether and recrystallized until no change takes place in the melting point. Palmitin forms small pearly scales. It is an entirely neutral, solid, fatty body, insoluble in water, scarcely soluble in cold alcohol, and but slightly so at the boiling temperature; it is easily soluble in hot ether, but on cooling the dissolved portion reseparates in white flakes.

The artificial formation of the glycerides has been referred to on p. 111. Artificial palmitin is obtained by heating 1 part glycerin with 10 parts palmitic acid.

In melting, palmitin exhibits a peculiar behavior somewhat similar to sulphur. It has three fusing points: On heating to 115° F. it becomes first liquid and transparent; by continuing the heating it again solidifies, fuses again temporarily at 143° F., and after becoming thick once more, finally remains fluid at 145° F. In cooling it solidifies to a transparent, waxy, brittle mass.

Dipalmitin, $(C_{15}H_{31}COO)_2.OH.C_3H_5'''$, is obtained by heating for 114 hours a mixture of 2 atoms of palmitic acid = 512 parts by weight, with 1 atom of glycerin = 92 parts by weight. It crystallizes in small microscopic scales, fuses at 138° F., and solidifies to a waxy mass at 124° F.

Monopalmitin, $C_{15}H_{31}COO.(OH)_2C_3H_5'''$, is formed in small quantities by storing for some time at an ordinary temperature a mixture of palmitic acid and glycerin; for large quantities the mixture is heated to 392° F. After removal of the excess of glycerin, the monopalmitin is purified with ether. It crystallizes in small needles, which fuse at 136.5° F., and solidify to a waxy mass at 113° F.

Stearin $(C_{18}H_{35}O)_3.O_3.C_3H_5''' = (C_{17}H_{35}COO)_3C_3H_5'''$.

	Atomic weight.	
57C	684	76.85 per cent.
110H	110	12.36 "
6O	96	10.79 "
1 molecule $C_{57}H_{110}O_6$	890	100.00

Stearin or tristearin closely resembles palmitin, and occurs in most fats, they being as a rule the harder the more the stearin predominates.

It is impossible to separate the stearin in natural fats from the palmitin and obtain it in a pure form, even remelting thirty times and more being without success. The purest stearin is obtained from the tallow of *Brindonia indica* by repeated crystallization from ether. Entirely pure it can only be obtained artificially by heating distearin with fifteen to twenty times its weight of stearic acid, at 518° F., in a sealed tube for three hours. Stearin crystallizes in pearly crystals, is sparingly soluble in cold alcohol and ether, but easily so at a boiling temperature. On cooling, however, it reseparates almost entirely from the hot solution, only about $\frac{1}{225}$ of the weight of stearin used remaining in solution.

In fusing, stearin shows the same peculiar behavior as palmitin. Specific gravity at 149.9° F. = 0.9245. Distils in vacuo without decomposition.

Stearin fusing at 145.4° F. solidifies again about 35.6° F. below this fusing point, provided it is heated not more than 33.8 or 35.6° F. above this fusing point; but, on the other hand, if heated 39.2° F. or more above this fusing point—145.4° F.—it solidifies 54.5° F. below it. Stearin solidifying 54.5° F. below its fusing point again becomes transparent, and fuses when heated 33.8° F. above its solidifying point, but with a constant or increasing temperature again becomes opaque. There are thus two modifications, one of stearin fusing at 145.4° F. and the other of stearin which, when heated 39.2° F. above its fusing point, solidifies 54.5° F. below it; after again solidifying it is converted into the first modification, with its fusing point at 145.4° F.

Stearin heated only 33.8° or 35.6° F. above its fusing point—145.4° F.—and gradually solidifying 33.8° or 35.6° F. below it, has been converted into a third modification, which fuses at 151.7° F., this being the fusing point of stearin crystallized from ether.

Modifications of stearin:

First modification, fusing point, 123.8° F.

Second modification, fusing point, 145.4° F.

Third modification, fusing point, 151.7° F.

In making experiments regarding expansion with stearin, which became transiently transparent at 122° F. and permanently fused at 140° F., H. Kopp observed that up to 122° F. it steadily expanded, but contracted at that temperature, and again expanded with an increase in the temperature.

Distearin, $(C_{17}H_{35}COO)_2.OH.C_3H_5'''$. Equal parts of stearic acid and glycerin are heated at 212° F. for 114 hours, or tristearin is heated with an excess of glycerin to 392° F. for 7 hours. It forms small white laminæ, fuses at 136.5° F., and solidifies to a hard, brittle, waxy mass at 131° F.

Monostearin, $C_{17}H_{35}COO(OH)_2C_3H_5'''$, is formed by heating a mixture of equal parts of stearic acid and glycerin at 392° F. for 36 hours. It crystallizes from ether in very small white needles, fusing at 142° F., and solidifying again to a hard, brittle, waxy mass at 140° F.

Margarin. This body was first described by Chevreul, who considered it a glyceride of margaric acid. According to its composition, margaric acid was supposed to be an intermediate product between palmitic and stearic acids, with 17 atoms of carbon $= C_{17}H_{44}O_2C_{16}H_{33}.COOH$, and this, in connection with glycerin, the *trimargarin* $= (C_{16}H_{33}COO)_3C_3H_5'''$. It has, however, been shown by Heintz that Chevreul's margarin is not a simple fat, but a mixture resolvable into stearic acid and other fatty acids of lower fusing points, chiefly palmitic acid.

Olein, $(C_{18}H_{33}O)_3.O_3.C_3H_5''' = (C_{17}H_{33}COOO)_3C_3H_5'''$.

	Atomic weight.	
57C	684	77.38 per cent.
104H	104	11.76 "
6O	96	10.86 "
1 molecule $C_{57}H_{104}O_6$	884	100.00

Olein, triolein, or elain, is a constituent of many fats and oils, of the fat of the pig and goose, of olive oil, oil of almonds, etc. To obtain nearly pure olein from natural fats, an oil or fat rich in oleic acid is cooled to below 32° F., and the liquid portion pressed from the solidified part at this temperature. The cold-pressed portion is then treated with soda lye, frequently shaken, and allowed to stand 24 hours. By this treatment all the stearin and palmitin are saponified, while the olein is but little attacked. The mixture is then compounded with weak alcohol, which dissolves the soaps formed, while the unaltered olein is entirely separated and floats upon the surface. It shows a slightly yellowish color, which is removed by warm treatment with animal charcoal and filtering.

Entirely pure olein can only be prepared by heating monolein with 15 to 20 times its weight of oleic acid to 464° F.

Olein is an inodorous, tasteless, colorless fluid, remaining liquid below 41° F., but solidifying at a lower temperature. Its specific gravity is 0.90 to 0.91 at 59° F. It is not soluble in water and dilute alcohol, but easily soluble in absolute alcohol and ether. It volatilizes with superheated steam or *in vacuo* without decomposition, but under ordinary atmospheric pressure it is decomposed on heating, yielding, besides acrolein, products of decomposition of oleic acid.

By plumbic oxide olein is slowly resolved into oleate of lead and glycerin. By carbonic acid and caustic alkalies it is decomposed much more slowly and with more difficulty than the corresponding combinations of stearate and palmitate.

Exposed to the air olein readily absorbs oxygen, yielding colored products of oxidation, which partly show an acid reaction. In an alkaline solution it rapidly absorbs ozone, and is oxidized to oenanthol $C_7H_{14}O$, the aldehyde of oenanthylic acid, $C_7H_{14}O_2 = C_6H_{13}.COOH$, to acrolein and other combinations.

By passing nitric or hyponitric acid into cold olein, it is converted into the isomeric *elaïdin*.

Diolein, $(C_{17}H_{33}COO)_2.OH.C_3H_5'''$, is obtained by heating triolein with glycerin to 392° F. It is a neutral fat of specific gravity 0.921, and commences to crystallize at 50° to 59° F.

Monolein, $C_{17}H_{33}COO.(OH)_2C_3H_5'''$, is obtained by heating a mixture of glycerin and oleic acid in sealed tubes to 392° F. for 18 hours. It is a neutral yellowish oil of specific gravity 0.947, almost odorless and tasteless. By rapid cooling it becomes solid at 32° F., and then fuses again at 50° F.

Elaïdin, $(C_{17}H_{32}COO)_3C_3H_5'''$, is the glyceride of elaïdic acid, $C_{18}H_{34}O_2 = C_{17}H_{33}.COOH$.

Poutet first observed, in 1819, the solidification of the olein of non-drying oils by the action of a solution of mercury in nitric acid. Boudet later on found this phenomenon to be due to the action of nitrous acid.

To prepare elaïdin, almond or olive oil, freed as much as possible from stearin and palmitin by chilling and treating with alcohol, is mixed with fuming nitric acid. In a few hours the mass solidifies; it is then pressed between paper, and, after washing with alcohol, recrystallized from ether.

Elaïdin is of a pure white color, very much resembles stearin, is insoluble in water, dissolves very sparingly in alcohol, but readily in ether and benzine. It fuses, according to Meyer, at 89.5° F., and, according to Duffy, at 100.5° F., solidifying at 82.5° F. By destructive distillation it is decomposed, yielding acrolein, elaïdic acid, and various hydrocarbons. By saponification it is resolved into alkaline elaïdate and glycerin.

Ricinelaïdin = *palmin*, $(C_{17}H_{34}COO)_3C_3H_5'''$, is formed by treating castor oil with nitrous acid. The castor oil solidifies in a short time and separates from a solution in ether in opaque non-crystalline grains, which fuse at 143.5° F., have an odor of oenanthol, are readily soluble in ether and alcohol, and by saponification yield glycerin and ricinelaïdic acid, and, by destructive distillation, oenanthol.

5. *Monatomic Acids of Saturated Hydrocarbons.*

Butyric acid, C_3H_7COOH = *normal butyric acid*, $CH_3.CH_2.CH_2.COOH$, to distinguish it from *isobutyric* acid = $(CH_3)_2.CH.COOH$). Butyric acid accurs as a triglyceride in butter, and was first investigated, 1814 to 1818, by Chevreul. It occurs also in the gastric juice, in the spleen, sweat, in old fruits of the soap tree (*Sapindus saponarius*) in those of the tamarind (*Tamarindus indica*), and in St. John's bread (fruit of *Ceratonia siliqua*). It is much more diffused in the animal than in the vegetable kingdom. It is formed by heating protein substances (glue, fibrin, albumen, casein) with soda-lime or with pyrolusite and sulphuric acid. It is best prepared from sugar by fermentation, lactic acid

$$\frac{2C_6H_{12}O_6}{\text{Inverted sugar}} = \frac{4C_3H_6O_3}{\text{Lactic acid}}$$

being first formed, which is then converted into butyric acid by the following equation:

$$\frac{2C_3.CH.OH.COOH}{\text{Lactic acid}} = \frac{2HH}{\text{Hydrogen}} + \frac{2CO_2}{\text{Carbonic acid}} + \frac{C_3H_7COOH}{\text{Butyric acid.}}$$

Normal butyric acid is formed by the oxidation of normal *butyl alcohol*, $CH_3.CH_2.CH_2.CH_2.OH$, and by boiling *butyronitril = propyl cyanide*, $C_3H_7.CN$, with potash lye. See "Margaric Acid."

From butter it is obtained simultaneously with other homologous liquid fatty acids—*caproic acid* $C_5H_{11}COOH$, *caprylic acid*, $C_7H_{15}COOH$, and *capric acid*, $C_9H_{19}COOH$—as follows:

Butter is saponified with soda lye, supersaturated with dilute sulphuric acid, and distilled, with frequent addition of water, as long as the distillate shows an acid reaction. The distillate is then saturated with barium water, brought to dryness, and the residue boiled with six times the quantity of water, whereby barium butyrate and caproate are dissolved, while barium caprylate and caprate remain in solution.

On crystallizing the mixture from the aqueous solution, barium caproate separates first and barium butyrate last. The barium salts of caprylic and capric acids remaining in solution are dissolved in a large quantity of hot water and crystallized from the solution, whereby barium caprate separates first.

The separate solutions of barium salts are mixed with dilute sulphuric acid, and subjected to distillation, simple decomposition being only necessary for barium caprate.

Butyric acid is a colorless liquid, with the odor of rancid butter, and an acid taste. Its specific gravity is 0.9886 at a medium temperature. Dropped upon sized paper it makes a grease stain, which, however, disappears later on. It attacks the skin like the strongest acids, is soluble in water, alcohol, and ether, but separates again from the aqueous solution if soluble salts are added. It remains fluid at 68° F., but on surrounding it with a mixture of solid carbonic acid and ether crystallizes in broad plates as clear as water.

Normal butyric acid boils without suffering decomposition at 312.8° F.; by distillation with concentrated sulphuric acid only a very small portion is decomposed, and by continued boiling with nitric acid succinic acid, $C_4H_6O_4 = COOH—CH_2—CH_2—COOH$, is formed.

$$\frac{C_3H_7COOH}{\text{Butyric acid}} + \frac{3O}{\text{Oxygen}} = \frac{HOH}{\text{Water}} + \frac{C_2H_4(COOH)_2}{\text{Succinic acid.}}$$

All butyrates are soluble in water, and most of them also in alcohol. Many of them when thrown upon water assume, before dissolving, a rotatory motion similar to camphor.

Isobutyric acid, $C_4H_8O_2 = C_3H_7.COOH = (CH_3)_2.CH.COOH$, occurs in St. John's bread (the fruit of *Ceratonia siliqua*), in the flowers of arnica (*Arnica montana* L.) as well as in croton oil. It is prepared in the above described manner from pseudo-propyl cyanide. It is a colorless fluid of a less disagreeable odor, boils at 309° F., and at 68° F. has a specific gravity = 0.9503.

Regarding the properties of *caproic*, *caprylic* and *capric* acids, see p. 108, and under "Butter."

Lauric acid, $C_{12}H_{24}O_2 = C_{17}H_{23}.COOH$, discovered by Marson in 1842, occurs in bay oil, cocoanut oil, dika fat, croton oil, spermaceti, etc. To prepare it laurostearin (page 131) is saponified with potash lye, the soap separated with common salt, and the impure acid, which is separated, several times recrystallized from dilute alcohol. Lauric acid forms white needles fusing at 110.5° to 113° F. to a thin oil, which solidifies to a scaly crystalline mass. It is insoluble in water, but freely soluble in alcohol and ether. The solution shows an acid reaction.

Myristic acid, $C_{14}H_{28}O_2 \Rightarrow C_{13}H_{27}.COOH$, was found by Playfair in expressed oil of nutmegs, and occurs also in dika fat, otoba butter (from *Myristica otoba*), in cocoanut oil and spermaceti, and, combined with lauric and palmitic acids, in many other fats. It is prepared by the saponification of expressed oil of nutmegs, separation of the myristic acid by a mineral acid, and repeated recrystallization from alcohol, or by fractional precipitation of the separated myristic acid with magnesium acetate.

Myristic acid is a snow-white, crystalline, scaly substance, insoluble in water, but freely soluble in hot alcohol and ether. It fuses at 129° F., and, on cooling, solidifies to a scaly crystalline mass. The alcoholic solution exhibits an acid reaction and expels carbonic acid from its salts.

In the same manner as on heating calcium acetate with an excess of calcium hydrate acetone is formed, carbonic acid being split off,

$$\frac{(CH_3COO)_2Ca''}{\text{Calcium acetate}} = \frac{CO.O_2.Ca''}{\text{Calcium carbonate}} + \frac{C_3H_6O}{\text{Acetone,}}$$

homologous acetones or ketones—palmiton, stearon, butyron, myriston, lauron, etc., are formed from palmitic, stearic, butyric, lauric and myristic acids.

Palmitic acid, $C_{16}H_{32}O_2 = C_{15}H_{31}.COOH$.

	Atomic weight.	
16C	192	75.00 per cent.
32H	32	12.50 "
2O	32	12.50 "
1 molecule $C_{16}H_{32}O_2$	256	100.00

Palmitic acid derives its name from having been first separated from palm oil. It occurs together with stearic and oleic acids in nearly all vegetable and animal fats. Palm oil, olive oil, Chinese tallow, Japanese wax, spermaceti, as well as bees' wax, contain it, partially in a free state. To prepare it, palm oil is saponified by boiling with potash or soda lye, the resulting soap after cooling is dissolved in hot water and decomposed by dilute hydrochloric acid. The mixture of palmitic and oleic acids floating upon the surface is freed as much as possible from oleic acid by pressure. The residue is dissolved in a little hot alcohol, and, after cooling, the solidified mass is again subjected to strong pressure between blotting-paper, and the operation (recrystallizing and pressing) repeated eight or nine times until the fusing point of the acid remains permanent at 143.5° F. The fusing point of the separate fatty acids is the higher the greater the percentage of carbon.

Palmitic acid can also be freed from the last trace of stearic acid by fractional precipitation. For this purpose the residue of solid acid, freed from oleic acid by repeated recrystallization, is dissolved in boiling alcohol and compounded with two-sevenths of its weight of barium acetate, previously dissolved in boiling alcohol. On cooling, the precipitate, which contains the greater portion of the stearic acid fixed on barium sulphate, is filtered and pressed. From the combined liquids running off the dissolved acid mixture, which is now especially rich in palmitic acid, is completely precipitated by an excess of barium acetate. The precipitate, consisting chiefly of barium palmitate, is filtered and the fatty acid separated by boiling with dilute hydrochloric acid. This last acid mixture is treated once or several times more in the same manner until the fusing point of the palmitic acid remains permanent at 143.5° F.

Palmitic acid may be prepared artificially by carefully fusing oleic acid, $C_{17}H_{33}COOH$, with potassium hydroxide, whereby, with evolution of hydrogen gas, potassium acetate and potassium palmitate are formed. All homologous acids exhibit the same behavior.

$$\frac{\mathrm{C_2{=}CH{-}COOH}}{\text{Acrylic acid}} + \frac{\mathrm{2KOH}}{\text{Potassium hydroxide}} = \frac{\mathrm{HH}}{\text{Hydrogen}} + \frac{\mathrm{CH_3COOK}}{\text{Sodium acetate}} + \frac{\mathrm{HCOOK}}{\text{Potassium formate.}}$$

$$\frac{\mathrm{C_{17}H_{33}COOH}}{\text{Oleic acid}} + \frac{\mathrm{2KOH}}{\text{Potassium hydroxide}} = \frac{\mathrm{HH}}{\text{Hydrogen}} + \frac{\mathrm{CH_3COOK}}{\text{Potassium acetate}} + \frac{\mathrm{C_{15}H_{31}COOK}}{\text{Potassium palmitate.}}$$

The equation of decomposition of oleic acid is valid also for the isomeric elaïdic acid.

The potassium salt is decomposed by hydróchloric acid and the separated palmitic acid purified by recrystallization from alcohol.

Palmitic acid crystallizes in fine white needles, which melt at 143.5° F. and solidify to a scaly crystalline mass, with a foliated fracture. It is odorless and tasteless, very friable, and lighter than water. It is insoluble in water, but readily soluble in boiling alcohol and ether. It reddens litmus paper. By exclusion of air it can be heated with soda-lime to 536° F. without suffering decomposition; by the admission of air some butyric acid is formed. It can be distilled almost without change.

Sodium palmitate, $C_{15}H_{31}COONa'$, separates from a hot alcoholic solution as a jelly-like mass, but by standing and the action of the alcohol is changed into colorless scales. In a little water it is soluble without decomposition, but with more water is more easily decomposed than the corresponding potassium salt.

Magnesium palmitate, $(C_{15}H_{31}COO)_2Mg''$, is precipitated as a snow-white, very light, crystalline powder. It is soluble in boiling alcohol, but on cooling is almost entirely reseparated. It fuses at 248° F. without suffering decomposition.

Barium palmitate, $(C_{15}H_{31}COO)_2Ba''$, is a white, pearly, crystalline powder, which does not become soft at 212° F., and decomposes before melting.

Cetyl palmitate, $C_{15}H_{31}COO.C_{16}H_{33}$, is the chief constituent of spermaceti, a fat found in the head cavities of various whales.

Myricyl palmitate, $C_{15}H_{31}COO.C_{30}H_{61}$, is a constituent of bees' wax.

Margaric acid, $C_{17}H_{34}O_2 = C_{16}H_{33}.COOH$. This acid, regarded by Chevreul and all succeeding chemists up to Heintz as occurring in all fats, has been shown by the latter to be a mixture of stearic and palmitic acids (see "Margarin," p. 135). In fact the margaric acid prepared from fats, the fusing point of which is most frequently given at 140° F., can not only be separated by fractional precipitation into stearic and palmitic acids, but by fusing together one part stearic acid with nine parts palmitic acid a mixture with a fusing point of 140° F. is obtained, which, like margaric acid, solidifies to an acicularly crystalline mass.

Artificially margaric acid may be prepared by boiling cetyl cyanide, $C_{16}H_{33}.CN$ with potash lye, in a similar manner as *formic acid* from *prussic acid* = $CN.H$, or *acetic acid* from methyl cyanide = $CH_3.CN$.

$$\frac{CH_3.CN}{\text{Methyl cyanide}} + \frac{KOH}{\text{Potassium hydroxide}} + \frac{HOH}{\text{Water}} = \frac{NH_3}{\text{Ammonia}} + \frac{CH_3COOK}{\text{Potassium acetate.}}$$

$$\frac{C_{16}H_{33}CN}{\text{Cetyl cyanide}} + \frac{KOH}{\text{Potassium hydroxide}} + \frac{HOH}{\text{Water}} = \frac{NH_3}{\text{Ammonia}} + \frac{C_{16}H_{33}COOK}{\text{Potassium margarate.}}$$

From the latter the margaric acid is separated by dilute sulphuric acid and obtained pure by recrystallization from hot alcohol.

Margaric acid resembles palmitic acid and stearic acid, and solidifies after fusing in crystalline scales.

It is a remarkable fact that mixtures of artificial margaric acid with palmitic and stearic acids solidify, like the pure acids, in crystalline scales, while mixtures of stearic and palmitic acids solidify acicularly. Furthermore, the fusing point of mixtures of margaric acid with the other two acids is not lowered to such an extent as that of mixtures of palmitic and stearic acids. The fusing point of artificial margaric acid lies at 152.6° F.

Stearic acid, $C_{18}H_{36}O_2 = C_{17}H_{35}.COOH$.

	Atomic weight.	
18C	216	76.06 per cent.
36H	36	12.67 "
2O	32	11.27 "
1 molecule = $C_{18}H_{36}O_2$	284	100.00

Stearic acid was discovered by Chevreul, and occurs as glyceride principally in the tallows and other fats already mentioned under stearin; it is also found in wool fat.

Pure stearic acid is most easily obtained from mutton suet, or the tallow of *Brindonia indica* and *Bassia Parkii.* After freeing the tallow as much as possible from oleic acid by pressure, it is saponified with one-quarter to one-third of its weight of caustic soda. The resulting soap is decomposed with boiling dilute hydrochloric acid, and the fatty acid freed from hydrochloric acid, sodium chloride, and glycerin by washing. On crystallizing the fatty acids from hot alcohol, the stearate separates first, while oleic acid remains in solution. The residue is pressed and recrystallization repeated from comparatively larger quantities of alcohol until the fusing point of the separated acid is permanent at 156° to 156.5° F. Like palmitic acid, stearic acid can also be purified by fractional precipitation. Dissolve four parts of the fatty acids, purified as above, in a large quantity of boiling alcohol, and mix the solution with boiling solution of one part of magnesium acetate in alcohol. The magnesium stearate, separating on cooling, is pressed and continuously boiled with a large quantity of dilute hydrochloric acid. The fatty acid liberated thereby is, when solidified, repeatedly recrystallized from hot alcohol.

Stearic acid crystallizes from alcohol in pearly needles and externally resembles palmitic acid. It expands very much when heated, especially at the moment of fusing, and in solidifying contracts to such an extent that the pieces appear full of holes and porous.

By taking the volume of stearic acid at 32° F. = 1, at 122° F. = 1.038, at 140° F. = 1.054, and at 163.4° F. = 1.079, it becomes at 158° F. by fusing = 1.198. At between 48° and 52° F. the specific gravity of stearic acid is equal to that of water.

Stearic acid is colorless, tasteless, and inodorous; it is insoluble in water but readily soluble in alcohol, and especially so in hot alcohol and ether. In a fused state it reddens litmus tincture, the same effect being also produced by a cold alcoholic solution, but on adding to the latter water until the acid is precipitated, the litmus tincture reassumes its blue color.

In vacuo—with 100 millimeters pressure at about 549° F.—stearic acid is volatile without change; also with high-pressure steam. When subjected to destructive distillation the greater portion passes over without alteration. The remainder undergoes a decomposition which cannot be expressed by a simple equation, several processes of decomposition taking place alongside one another.

This portion of the stearic acid is resolved, on the one hand, into carbonic acid, water and *stearon* = ketone of stearic acid = $C_{17}H_{35}.CO.C_{17}H_{35}$, and, on the other, into acetic, butyric and other fatty acids, as well as into hydrocarbons of the general formula C_nH_n. The ketone or acetone of stearic acid = stearon, is also formed in the destructive distillation of the calcium salt $(C_{17}H_{35}COO)_2Ca''$; it fuses at 189.5° F. and crystallizes from hot ether in lustrous laminæ. Palmitic acid suffers the same decomposition into *palmiton*, $C_{15}H_{31}.C_{15}O.C_{31}H$, which forms crystals fusing at 183° F.

Chlorine converts stearic acid, at 212° F., into *chlorostearic acid*, and bromine, at the same temperature, into *bromostearic acid.*

$$\underbrace{C_{17}H_{35}COOH}_{\text{Stearic acid}} + \underbrace{ClCl}_{\text{Chlorine}} = HCl + \underbrace{C_{17}H_{34}ClCOOH}_{\text{Chlorostearic acid.}}$$

By boiling with nitric acid, stearic acid yields acids homologous to oxalic acid.

In regard to the *oxy-fatty acids* of stearic acid see p. 116, and *linoleic acid* further on.

Of the *metallic stearates* only those with an alkaline basis—sodium or potassium—are soluble in water, and they possess the same property as the palmitates, see p. 144, of being decomposed by dilution with much water into free alkali and insoluble acid salt. The other salts are obtained like the corresponding palmitate combinations by double decompositions, and also possess almost the same properties.

Arachidic acid, $C_{20}H_{40}O_2 = C_{19}H_{39}.COOH$, occurs as glyceride in the fat of the peanut (*Arachis hypogæa*), in Rambutan tallow, in the fats of the olive and hazel nut, in sunflower oil, butter, etc. It is prepared in the same manner as palmitic acid, and crystallizes in small shining laminæ.

Amongst others, *cocinic acid*, $C_{11}H_{22}O_2$, has been mentioned by St. Evre as an independent fatty acid occurring in cocoanut fat, but Heintz has proved it to be a mixture of laurostearic and capric acids, and a similar acid mentioned by Bromeis, a mixture of laurostearic and myristic acids. He has also shown that only fatty acids with even carbon-atoms occur in the natural fats and oils of the vegetable kingdom.

The following acids were formerly considered independent acids in fats and oils:

COMPOSITION AND FUSING POINTS OF FATTY ACIDS OF THE METHANE SERIES WITH ODD CARBON ATOMS.

Acids with odd carbon atoms.	Formula.	Fusing point.
Phocinic acid*	$C_5H_{10}O_2$	Boiling point 347° F.
Cocinic acid	$C_{13}H_{26}O_2$	105° F.
Cetic acid	$C_{15}H_{30}O_2$	123.8° F.
Margaric acid	$C_{17}H_{34}O_2$	139.8° F.
Medullic acid	$C_{21}H_{42}O_2$	162.5° F.
Hyaenic acid	$C_{25}H_{50}O_2$	171.5° F.
Cerotic acid	$C_{27}H_{54}O_2$	172.4° F.

Acids with odd carbon-atoms can be prepared in a manner analogous to margaric acid (p. 142).

In his investigations of spermaceti, Heintz by careful fusing experiments has also confirmed the observation previously made, that the mixture obtained by combining two homologous fatty acids in certain proportions has a lower fusing point than each separate acid.

While the boiling point (hence it may be supposed the fusing point also) of the volatile fatty acid rises with the increase in CH_2, Bayer has shown that the fusing point rises only with the even carbon-atoms, but with uneven carbon-atoms the fusing point lies below that of the two fatty acids with even carbon-atoms.

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* Identical with valeric acid in train-oils; hircic acid in goat tallow = butyric acid, $C_4H_8O_2$. Dbeglic acid, $C_{19}H_{36}O_2$ in oil from the bottlenose whale. fuses at 60.5° F.

During his investigations Heintz has also observed, besides the proportions of quantity, the properties of the solidified mixtures, and found that, while some show a crystalline structure, others are entirely non-crystalline.

On account of the importance of the subject, which gives to the manufacturer of stearin useful points in regard to the nature and value of his products of saponification, we give Heintz's observations in the following tables:

1. MYRISTIC AND LAURIC ACIDS.

A mixture of				
Myristic acid $C_{14}H_{27}O.HO$	Lauric acid, $C_{12}H_{23}O.HO$	Fuses at Degrees F.	Solidifies at Degrees F.	Manner of Solidifying.
100 parts	0 parts	138.0°	....	Scaly crystalline.
90 "	10 "	125.0	117.0°	Same.
80 "	20 "	121.0	112.0	Extremely fine crystalline.
70 "	30 "	116.0	102.0	Same.
60 "	40 "	109.5	102.0	Non-crystalline.
50 "	50 "	99.0	96.0	Large-foliated crystalline.
40 "	60 "	98.0	92.0	Non crystalline.
30 "	70 "	95.0	90.0	Non-crystalline, woolly.
20 "	80 "	101.0	91.5	Same.
10 "	90 "	106.0	97.0	Acicularly crystalline.
0 "	100 "	110.5	....	Scaly crystalline.

2. PALMITIC AND MYRISTIC ACIDS.

A mixture of				
Palmitic acid, $C_{16}H_{31}O.HO$	Myristic acid, $C_{14}H_{27}O.HO$	Fuses at Degrees F.	Solidifies at Degrees F.	Manner of Solidifying.
100 parts	0 parts	143.5°	....	Scaly crystalline.
95 "	5 "	142.0	136.5°	Same.
90 "	10 "	140.0	132.0	Same.
80 "	20 "	136.5	128.0	Scaly and indistinctly acicularly.
70 "	30 "	131.0	124.0	In extremely fine needles.
60 "	40 "	125.0	121.0	Non-crystalline, rugged.
50 "	50 "	118.0	113.5	Large-foliated crystalline.
40 "	60 "	116.5	110.5	Indistinctly foliated.
35 "	65 "	115.5	110.5	Non-crystalline, opaque.
32.5 "	67.5 "	115.0	111.0	Same.
30 "	70 "	115.0	110.5	Same.
20 "	80 "	121.0	106.0	Non-crystalline.
10 "	90 "	125.0	113.5	In long needles.
0 "	100 "	129.0	....	Scaly crystalline.

3. Stearic and Palmitic Acids.

A mixture of		Fuses at Degrees F.	Solidifies at Degrees F.	Manner of Solidifying.
Stearic acid, $C_{18}H_{35}O.HO$	Palmitic acid, $C_{16}H_{31}O.HO$			
100 parts	0 parts	156.5°	....	Scaly crystalline.
90 "	10 "	153.0	144.5°	Same.
80 "	20 "	149.5	140.5	Finely acicularly crystalline.
70 "	30 "	145.0	139.0	Same.
60 "	40 "	140.5	134.0	Non-crystalline, rugged.
50 "	50 "	134.0	131.0	Large-foliated crystalline.
40 "	60 "	133.0	130.0	Same.
35 "	65 "	132.0	130.0	Non-crystalline, wavy, lustrous.
32.5 "	67.5 "	131.0	129.0	Same.
30 "	70 "	131.0	129.0	Non-crystalline, wavy, lustreless.
20 "	80 "	135.5	129.0	Very indistinctly acicularly.
10 "	90 "	140.0	130.0	Beautifully acicularly crystalline.
0 "	100 "	143.5	....	Scaly crystalline.

4. Stearic and Myristic Acids.

A mixture of		Fuses at Degrees F.	Manner of Solidifying.
Stearic acid, $C_{18}H_{35}O.HO$	Myristic acid, $C_{14}H_{27}O.HO$		
100 parts	0 parts	156.5°	Scaly crystalline.
90 "	10 "	153.0	Still more distinctly scaly crystalline.
80 "	20 "	149.0	Somewhat less distinctly scaly crystalline.
70 "	30 "	145.0	Still less distinctly scaly crystalline, no trace of needles.
60 "	40 "	139.5	Commencement of scaly crystallization, no trace of needles.
50 "	50 "	130.0	Non-crystalline, opaque.
40 "	60 "	123.0	Beautifully large-foliated crystalline.
30 "	70 "	119.0	Foliated crystalline.
20 "	80 "	118.0	Indistinctly crystalline.
10 "	90 "	125.0	Non-crystalline, opaque.
0 "	100 "	129.0	Scaly crystalline.

5. Palmitic and Lauric Acids.

A mixture of		Fuses at Degrees F.	Manner of Solidifying.
Palmitic acid, $C_{16}H_{31}O.HO$	Lauric acid, $C_{12}H_{23}O.HO$		
100 parts	0 parts	143.5°	Scaly crystalline.
90 “	10 “	139.5	Distinctly scaly crystalline.
80 “	20 “	135.0	Somewhat less distinctly scaly crystalline.
70 “	30 “	130.0	Still less distinctly scaly crystalline.
60 “	40 “	124.0	Granular, indistinctly scaly crystalline.
50 “	50 “	116.5	Almost entirely non-crystalline, opaque.
40 “	60 “	104.0	Large-foliated crystalline.
30 “	70 “	101.0	Small-foliated crystalline.
20 “	80 “	99.0	Finely crystalline, indistinct.
10 “	90 “	107.0	Non-crystalline.
0 “	100 “	110.5	Scaly crystalline.

6. Stearic and Lauric Acids.

A mixture of		Fuses at Degrees F.	Manner of Solidifying.
Stearic acid, $C_{18}H_{35}O.HO$	Lauric acid, $C_{12}H_{23}O.HO$		
100 parts	0 parts	156.5°	Scaly crystalline.
90 “	10 “	152.5	Distinctly scaly crystalline.
80 “	20 “	148.0	Same.
70 “	30 “	143.5	Distinctly granular crystalline.
60 “	40 “	138.0	Granular, commencemeut of scaly crystallization.
50 “	50 “	132.5	Nearly crystalline, slightly granular.
40 “	60 “	123.5	Non-crystalline, warty.
30 “	70 “	110.0	Upon the surface, areas of small shiny crystals.
20 “	80 “	101.0	Non-crystalline, warty.
10 “	90 “	107.0	Non-crystalline.
0 “	100 “	110.5	Scaly crystalline.

7. MARGARIC ACID (FROM CYANCETYL) AND MYRISTIC ACID.

A mixture of			
Margaric acid, $C_{17}H_{33}O.HO$	Myristic acid, $C_{14}H_{27}O.HO$	Fuses at Degrees F.	Manner of Solidifying.
100 parts	0 parts	140.0°	Scaly crystalline.
90 "	10 "	135.0	Same.
80 "	20 "	132.0	Indistinctly crystalline. [surface.
70 "	30 "	128.0	Almost entirely non-crystalline with level
60 "	40 "	123.0	Amorphous, opaque.
50 "	50 "	115.0	Same.
40 "	60 "	114.0	Somewhat granular, crystalline.
30 "	70 "	112.5	Same, with larger grains.
20 "	80 "	120.0	Same, grains very indistinct. [needles.
10 "	90 "	125.0	Opaque, in scarcely perceptible concentric
0 "	100 "	129.0	Scaly crystalline.

8. MARGARIC ACID (FROM CYANCETYL) AND PALMITIC ACID.

A mixture of			
Margaric acid, $C_{17}H_{33}O.HO$	Palmitic acid, $C_{16}H_{31}O.HO$	Fuses at Degrees F.	Manner of Solidifying.
100 parts	0 parts	140.0°	Scaly crystalline.
90 "	10 "	138.0	Same.
80 "	20 "	136.0	Same, though somewhat flowery.
70 "	30 "	134.5	Same.
60 "	40. "	134.0	Same.
50 "	50 "	133.0	Same.
40 "	60 "	133.0	Same.
30 "	70 "	134.5	Flowery, almost in long needles.
20 "	80 "	137.5	In long needles.
10 "	90 "	141.0	Same.
0 "	100 "	143.5	Scaly crystalline.

The mixtures of the above acids solidify partly like the pure acids, which contain 80 to 90 per cent. of palmitic acid, in beautiful long needles, in the same manner as the mixture of stearic and palmitic acids, formerly called margaric acid.

9. Stearic and Margaric Acids (from Cyancetyl).

A mixture of		Fuses at Degrees F.	Manner of Solidifying.
Stearic acid, $C_{18}H_{35}O.HO$	Margaric acid, $C_{17}H_{33}O.HO$		
100 parts	0 parts	157.0°	Scaly crystalline.
90 "	10 "	153.5	Same.
80 "	20 "	150.0	Same.
70 "	30 "	148.5	Same.
60 "	40 "	145.5	Same.
50 "	50 "	143.5	Same, but more pearly.
40 "	60 "	142.0	Same.
30 "	70 "	141.5	Same.
20 "	80 "	139.5	Same.
10 "	90 "	139.0	Same.
0 "	100 "	140.0	Scaly crystalline.

The mixtures of both fatty acids fuse more freely than stearic acid, but only in a moderate degree more so than margaric acid. They solidify almost like unmixed fatty acids, and also behave differently from the mixtures of stearic and palmitic acids.

With a mixture of two fatty acids, the fusing point of which is itself lower than that of each of the two acids, the fusing point becomes still lower by adding a determined quantity of a third acid; and, what is especially remarkable, even when this third acid has a greater atomic weight and higher fusing point than the first two acids.

The fusing point of a mixture of 30 parts of palmitic acid and 70 parts of myristic acid is at 115.0° F., but it sinks still lower by adding to 20 parts of the mixture up to 7 parts of stearic acid.

10. Palmitic, Myristic, and Stearic Acids.

20 parts of a mixture of 30 parts of palmitic acid and 70 parts of myristic acid.	Stearic acid.	Fuses at Degrees F.	Manner of Solidifying.
		115.0°	Non-crystalline.
	1 part	113.0	"
	2 parts	112.0	"
	3 "	111.0	"
	4 "	111.0	"
	5 "	112.0	"
	6 "	113.5	"
	7 "	115.0	"
	8 "	116.0	"

The fusing point of a mixture of 30 parts of myristic acid and 70 parts of lauric acid, which fuses at 95.0° F., changes as follows by adding to 20 parts of the mixture 1 to 10 parts of palmitic acid:

11. MYRISTIC, LAURIC, AND PALMITIC ACIDS.

20 parts of a mixture of 30 parts of myristic acid and 70 parts of lauric acid.	Palmitic acid.	Fuses at Degrees F.	Manner of Solidifying.
		95.0°	Non-crystalline.
	1 part	93.0	"
	2 parts	91.5	"
	3 "	90.0	"
	4 "	91.0	"
	5 "	93.0	"
	6 "	94.0	"
	7 "	95.5	"
	8 "	96.8	"
	9 "	99.0	Indistinctly fine acicularly.
	10 "	102.0	Fine acicularly.

The phenomena in fusing together fatty acids are similar to to those in metals. By fusing together two metals the fusing point is frequently considerably lowered, and by adding a third or fourth metal it sinks even below the boiling point of water. Bismuth, for instance, fuses at 475.0° F., lead at 633.0° F., and tin at 455° F.; an alloy of 2 parts of bismuth, 1 part of lead, and 1 part of tin, known as Rose's metal, fuses at 200.75° F., and an alloy called Wood's metal, containing cadmium as a fourth metal, at 154.4° F.

6. *Monatomic Acids of the Non-saturated Hydrocarbons.*

Oleic acid, *acetopalmitic acid*, $C_{18}H_{34}O_2 = C_{17}H_{33}.COOH$.

	Atomic weight.	
18C	216	76.60 per cent.
34H	34	12.06 "
2O	32	11.34 "
1 molecule $C_{18}H_{34}O_2$	282	100.00

Oleic acid or elaïc acid forms as trioleïn a constituent of nearly all natural non-drying fats, which, as a rule, are the more limpid the greater the quantity of oleic acid they contain. To prepare the acid a fat rich in the glyceride of oleic acid, for instance almond or olive oil, or goose grease, is saponified by boiling with potash lye, and the resulting soap decomposed with hydrochloric acid. The separated fatty acids are digested with lead oxide for several hours at 212° F. The mixture of oleate, palmitate and stearate of lead is exhausted with cold ether, which dissolves only lead oleate, the lead salts of the solid fatty acids remaining in solution. The ethereal solution is filtered and shaken with an equal volume of water, to which has been added sufficient hydrochloric acid for the saturation of the lead oxide. The oleic acid separated thereby remains dissolved in the ether, while the lead chloride is quickly deposited from the lower aqueous solution.

The filtered ethereal solution is poured off from the lead chloride and evaporated, leaving impure oleic acid behind, which can be obtained pure by two methods:

a. To separate the products of oxidation and the coloring substances, the impure acid is dissolved in an excess of ammonia and precipitated with barium chloride. The resulting barium oleate is repeatedly boiled with alcohol, and the crystalline scales precipitated on cooling are several times recrystallized from alcohol. The barium oleate is finally decomposed in a closed vessel with tartaric acid, and the pure oleic acid thus obtained freed from adhering tartaric acid by washing with cold water.

b. The oleic acid separated from the lead oleate is exposed to a temperature of from 21.2° to 19° F., whereby the pure oleic acid solidifies. The solidified mass is freed from adhering fluid products of oxidation of oleic acid by pressure between blotting-paper. This operation is several times repeated with the acid previously fused in a warm place. To remove, however, the last traces of admixed fluid coloring substances, the oleic acid is to be dissolved in very little alcohol and the solution exposed to the cold. The oleic acid, crystallizing in beautiful snow-white needles, is, after repeated pressure, entirely pure, and when dried in a current of carbonic acid to prevent oxidation, fuses at 39.2° F.

Pure oleic acid at a temperature above 39° F. is a colorless, oily fluid, without odor or taste, clear as water, and does not redden litmus paper either by itself or in alcoholic solution. It is insoluble in water, but readily soluble in alcohol and ether.

At 39° F. it solidifies to a white, hard crystalline mass, the crystals contracting thereby to such an extent that the portion remaining fluid is pressed out and forced to the surface. Solid oleic acid remains quite unaltered in the air, but in a fluid state it rapidly absorbs oxygen—at 59° F. about twenty times its volume—acquires a brown color, a rancid taste and odor, and reddens litmus. The absorption of oxygen takes place still more rapidly at 212° F., the oleic acid then losing its property of solidifying at a lower temperature.

In a vacuum oleic acid volatilizes without decomposition; like all fatty acids, it can be distilled in a current of superheated steam. If the temperature, however, exceeds 482° F. it is resolved into acetic acid, butyric acid, paraffin, etc.

By destructive distillation oleic acid is decomposed, but little of it passing unaltered into the receiver. During the entire process of distillation gases consisting of carbonic acid and hydrocarbons are quite uniformly evolved, while in the distillate *sebacic acid*, $C_8H_{16}(COOH)_2$, *acetic acid*, *caprylic acid* and other homologous fatty acids are found as chief products of decomposition. But little coal remains behind in the retort.

A mixture of 10 parts of oleic acid with 3 parts of calcium hydrate and 3 parts of soda-lime yields, on heating, hydrocarbons of the formula C_nH_{2n}, ethylenes, propylenes, butylenes, and amylenes, and especially propylenes, in such large quantities that this mode of preparation deserves preference above all others.

By fusing oleic acid with caustic potash it is resolved into acetic and palmitic acids.

$$\frac{C_{17}H_{33}COOH}{\text{Oleic acid}} + \frac{2KOH}{\text{Potassium hydroxide}} = \frac{HH}{\text{Hydrogen}} + \frac{CH_3COOK}{\text{Potassium acetate}} + \frac{C_{15}H_{31}COOK}{\text{Potassium palmitate.}}$$

This conversion also explains the fact that by the saponification of fats and oils with sulphuric acid more solid fats are obtained than by the saponification with lime.

To utilize in the fabrication of candles the large quantities of oleic acid which are obtained as a by-product of comparatively little value in the manufacture of stearic acid, it is decomposed according to the above process. Not only the palmitic acid is obtained, but by decomposing the fused mass with sulphuric acid, the acetic acid may also be obtained by distillation.

In the presence of water, chlorine and bromine form with oleic acid, chloroleic and bromoleic acids.

$$\frac{C_{17}H_{33}COOH}{\text{Oleic acid}} + \frac{BrBr}{\text{Bromine}} = \frac{HBr}{\text{Hydrobromic acid}} + \frac{C_{17}H_{32}BrCOOH}{\text{Bromoleic acid.}}$$

Iodine does not act upon oleic acid.

The fat oils of oleic. acid when shaken with alcoholic ammonia solution and allowed to stand several months are changed into an amide combination of oleic acid which corresponds to the combinations of palmitic and stearic acids.

$$\frac{C_{16}H_{31}OH_2N}{\text{Palmitinamide}} \qquad \frac{C_{18}H_{35}OH_2N}{\text{Stearinamide}} \qquad \frac{C_{18}H_{33}OH_2N}{\text{Oleolamide.}}$$

By boiling with nitric acid, oleic acid is readily oxidized and converted into various volatile and non-volatile acids. In the distillation acetic acid and the fatty acids richer in carbon up to capric acid pass into the receiver, while suberic acid, $C_8H_{14}O = C_6H_{10}(COOH)_2$, besides other members of the oxalic acid series, to which sebacic acid also belongs, remain in the retort.

The diatomic acids of the oxalic acid series are derived from the general formula $C_nH_{2n}(COOH)_2$.

With sulphuric acid, oleic acid yields an *oleosulphuric acid* which forms a clear, pale yellow, strongly acid fluid, of specific gravity 1.03. However, according to recent researches by Geitel, this acid is not formed by treating oleic acid or olein with sulphuric acid, but a mixture of stearosulphuric, distearosulphuric, oxystearic, etc., acids.

By nitrous acid oleic acid is in a short time converted into the isomeric elaïdic acid.

The salts of pure oleic acid have not been thoroughly investigated, and some of them are difficult to prepare on account of their inclination to produce acid and basic salts.

The alkaline carbonates are decomposed in the heat by oleic acid, carbonic acid being very slowly evolved. The alkaline salts are readily soluble in water, while those of the alkaline earths and heavy metallic oxides are insoluble in water and dissolve with difficulty in alcohol, though some of them dissolve readily in ether. The latter property, especially of the lead salt, furnishes a means of separating the oleic acid from stearic, palmitic and several other acids, whose lead combinations are insoluble in ether.

By oxidation with potassium permangate of oleic and elaïdic acids in alkaline solution, *dioxystearic acid*, $C_{17}H_{33}(OH)_2COOH$, and *isodioxystearic acid*, $C_{17}H_{33}(OH)_2COOH$ are, according to Saytzeff, formed.

Lead oleate, $(C_{17}H_{33}COO)_2Pb''$, is deposited as a white flaky precipitate on mixing an aqueous alcoholic solution of sodium oleate with a solution of lead acetate. When quickly filtered, washed in a cool place, and dried in *vacuo*, it presents a white loose powder, which fuses to a yellow fluid at 176° F., but on cooling the lead oleate becomes rigid and brittle, remaining, however, transparent.

Lead oleate forms the chief constituent of the ordinary lead plaster of the drug stores.

M. C. and A. Saytzeff lay claim to the discovery of *isoleic acid* or *solid oleic acid*, they having prepared it by the action of alcoholic potash lye upon *iodostearic acid* obtained by the action of hydriodic acid upon oleic acid. They give for both acids the following formulæ:

$$1.\ \underline{CH_3-(CH_2)_{13}-CH=CH-CH_2-COOH}$$

Ordinary oleic acid.

$$2.\ \underline{CH_3-(CH_2)_{13}-CH_2-CH=CH-COOH}$$

Isoleic acid or solid oleic acid.

Isoleic acid fuses at 109.5 to 113° F., and solidifies at 111 to to 109° F. From ether it crystallizes in rhombic crystals. It resembles elaïdic acid, but is said not to be identical with it. The latter fuses at 111.2 to 113° F., and solidifies at 107.6° F.

Elaïdic acid, $C_{17}H_{33}COOH$. This name has been given to the isomeric acid, into which oleic acid is converted by treatment with nitrous acid.

It is prepared by passing for about five minutes nitrous acid into cold oleic acid. In about half an hour it solidifies to a foliated mass, which is repeatedly washed with boiling water, and the product finally crystallized from alcohol.

Elaïdic acid, prepared by saponification of elaïdin and decomposition of the soap, cannot be obtained pure by recrystallization.

Elaïdic acid crystallizes from an alcoholic solution in shining scales, fusing at 111.2° to 113° F., and solidifying with strong expansion, at 107.6° F. The scales are soluble in ether, but not in water. Elaïdic acid is stable in the air, and can be volatilized without decomposition. Heated for some time at 149° F. it absorbs oxygen from the air, remains fluid on cooling, and is not again solidified by nitrous acid. When fused with caustic potash it resolves, like oleic acid, into palmitic and acetic acids. It shows a strong acid reaction, forces the carbonic acid from the carbonates, and yields with alkalies clear soaps of very thick consistency.

Ricinoleic acid, $C_{18}H_{34}O_3 = C_{17}H_{32}.OH.COOH$.

	Atomic Weight.	
18C	216	73.23 per cent.
34H	34	11.59 "
3O	48	16.11 "
1 molecule $C_{18}H_{34}O_3$	298	100.00

Ricinoleic acid is found in castor oil and the oil of *Jatropha curcas* (purgir nut oil). It possesses nearly the same physical properties as oleic acid. Chemically it differs from it in having one atom more of oxygen. It is isomeric with *oxyoleic acid* $C_{47}H_{31}.OH.COOH$, which is obtained by treating *dibromoleic acid* $C_{17}H_{31}Br_2COOH$, with silver oxide.

$$\underset{\text{Dibromoleic acid}}{C_{17}H_{31}Br_2COOH} + \underset{\text{Silver oxide}}{AgOAg} = \underset{\text{Argentic bromide}}{2(AgBr)} + \underset{\text{Oxyoleic acid.}}{C_{17}H_{32}.OHCOOH}$$

Ricinoleic acid is prepared in a manner similar to oleic acid. Castor oil is saponified with caustic potash or caustic soda solution, the resulting soap decomposed by heating for a short time with hydrochloric acid, the ricinoleic acid separating on the surface mixed with a small quantity of alcohol, and cooled to 10.5° F. to separate the admixed solid fatty acids. For complete purification the ricinoleic acid is converted into the lead salt, the latter extracted with ether and decomposed in ethereal solution with hydrochloric acid. The acid remaining behind after the evaporation of the ether is finally converted into the barium salt, which is purified by repeated recrystallization from alcohol, and again decomposed with hydrochloric acid.

Ricinoleic acid is a colorless, inodorous oil of an acrid taste and the consistency of syrup. It has a specific gravity of 0.940 at 15° F. At 32° F. it solidifies to a crystallized mass. It is soluble in alcohol and ether but not in water, and does not absorb oxygen from the air. In alcoholic solution it reddens blue litmus tincture, and expels carbonic acid from its salts.

When subjected to destructive distillation ricinoleic acid does not yield sebacic acid; however, when heated with soda lye sebacic acid is formed with simultaneous formation of secondary *octyl alcohol* and *methyl-hexyl ketone*, and the evolution of hydrogen.

$$1.\ \frac{C_{17}H_{32}.OH.COONa}{\text{Sodium ricinoleate}} + NaOH + HOH = \frac{C_8H_{17}.OH}{\text{Octyl alcohol}} +$$

$$2H + \frac{C_8H_{16}.(COONa)_2}{\text{Sodium sebacate.}}$$

$$2.\ \frac{C_{17}H_{32}.OH.COONa}{\text{Sodium ricinoleate}}$$

$$NaOH + HOH = \frac{CH_3.CO.C_6H_{13}}{\text{Methyl-hexyl ketone}} + 4H + \frac{C_8H_{16}(COONa)_2}{\text{Sodium sebacate.}}$$

According to how distillation is managed there are also formed at 482° F. *œnanthol = heptyl aldehyde*, $C_7H_{14}O$, and *œnanthalcohol = heptyl alcohol.*

Castor oil mixed with ammonia solidifies in a few weeks to colorless warts which fuse at 151° F., and are soluble in alcohol and ether, but not in water. They constitute an ammoniacal combination—*ricinolamide* $C_{18}H_{33}O_2.H_2N$—which is formed in the same manner as the acetamides.

K. Hazura has found that ricinoleic acid, when oxidized, yields *trioxy-stearic acid*, which can be split into ordinary trioxy-stearic acid, fusing at 284° to 287.5° F., and into *isotrioxy-stearic acid*, fusing at 230° to 232° F., from which he infers the presence in castor oil of two isomeric acids—*ricinoleic and isoricinoleic acids.* Oleic acid does not occur in castor oil.

By nitrous acid ricinoleic acid is converted into *ricinelaïdic acid.*

Ricinelaïdic acid, $C_{17}H_{33}COOH$, crystallizes in concentrically united needles, fuses at 122° F., and solidifies to a radiated crystalline mass at 118.5° F. It dissolves in all proportions in alcohol and ether.

Hypogæic acid and physetoleic acid, $C_{16}H_{30}O_2 = C_{15}H_{29}.COOH$.

	Atomic weight.	
16C	192	75.59 per cent.
30H	30	11.81 "
2O	32	12.60 "
1 molecule $C_{16}H_{30}O_2$	254	100.00

Hypogaeic acid was found by Goessmann and Scheven in the oil of the peanut (*Arachis hypogæa*), and is identical with *physetoleic acid*, $C_{16}H_{30}O_2$, prepared by Hofstaedter from the oil contained in the cavities of the head of the sperm whale (*Physeter macrocephalus*). It stands in the same homologous relation to oleic acid, as palmitic acid to stearic acid; *i. e.*, it is distinguished from it by a difference of composition of $2(CH_2) = C_2H_4$.

Hypogæic acid is isolated from peanut oil in the following manner: The fatty acids separated from the oil after saponification of the oleic acid are dissolved in a sufficient quantity of alcohol, and the arachidic and palmitic acids partly precipitated by magnesium acetate and ammonia; all that is precipitated is filtered off. The filtrate, which contains the hypogæic acid, is mixed with an alcoholic solution of lead acetate and ammonia (both in excess) and the mixture allowed to stand quietly for several days. The precipitate is then collected upon a filter, washed with alcohol, dried as quickly as possible by pressing, and completely exhausted with ether in a closed cylinder. The ether dissolves the lead hypogate; the lead combinations of arachidic acid, palmitic acid, etc., remain in solution. On account of the easy alteration of hypogæic acid by the absorption of oxygen, the ethereal solution is compounded with an excess of dilute hydrochloric acid, the precipitate of lead chloride filtered off, and the filtrate once more thoroughly shaken with boiled water.

The ethereal solution of hypogæic acid is then allowed to separate, lifted off, and the greater portion of the ether distilled off. From the residue, placed in a cold place, shoot out yellowish crystals, which are purified by pressing and repeated recrystallization from alcohol at a very low temperature.

For the isolation of *physetoleic acid* from spermaceti oil, the latter is saponified with potash lye, the resulting soap purified by salting, then dissolved in boiling alcohol and the solution mixed with solution of lead acetate and ammonia. It is then allowed to settle, when the precipitate formed is washed and dried in the air. Ether is then poured over the dry precipitate, whereby the lead *physetoleate*, besides *ethalcetyl alcohol*, $C_{16}H_{34}O_2$, and undecomposed spermaceti are dissolved and the lead salts of palmitic acid remain behind. A portion of the ether is now distilled off from the solution and the residue decomposed with dilute hydrochloric acid. To the ethereal solution is added solution of barium chloride and ammonia, the precipitate collected, dried in vacuo and the cetyl alcohol and undecomposed spermaceti extracted with cold ether. The barium physetoleate remaining undissolved is repeatedly boiled with 93 per cent. alcohol, and the resulting solutions allowed to cool separately. The portion taken up by the alcohol precipitates in the form of a white powder, which is collected, dried under the air-pump over sulphuric acid, and decomposed with alcoholic tartaric acid solution.

Hypogæic acid and physetoleic acid thus prepared form colorless and odorless acicular aggregates, insoluble in water but readily soluble in alcohol and ether. Hypogæic acid fuses at 93° to 95° F.; and physetoleic acid, according to Hofstaedter, at 86° F. On exposure to the air both acids acquire a reddish color and a very rancid odor, and show an acid reaction. The acids thus changed crystallize with difficulty even at a very low temperature. In common with *oleic and erucic acid* = $C_{21}H_{41}COOH$, hypogæic acid possesses the property of readily absorbing oxygen from the air, undergoing thereby decomposition.

By subjecting physetoleic acid to destructive distillation a yellowish fluid first passes over, then crystalline sebacic acid, $C_8H_{16}(COOH)_2$, and finally a stinking oil, while a small quantity of coal remains behind.

In the same manner as oleic acid, by fusing with potassium hydroxide, is converted into palmitic acid and acetic acid, hypogæic acid is decomposed into myristic acid.

$$\frac{C_{15}H_{29}COOH}{\text{Hypogæic acid}} + \frac{2HOH}{\text{Water}} = \frac{C_3H_5COOH}{\text{Acetic acid}} + \frac{C_{13}H_{27}COOH}{\text{Myristic acid.}}$$

Without taking part in the decomposition, nitrous acid possesses the remarkable property of converting hypogæic acid into an isomeric combination with a higher fusing point—*gaïdic acid*—while physetoleic acid is not attacked.

Gaïdic acid, $C_{15}H_{29}COOH$. By the introduction for two or three hours of nitrous acid into pure hypogaeic acid, the latter is converted into gaïdic acid. To remove oil-like admixtures the mass is subjected to strong pressure and purified by repeated crystallization from alcohol. Gaïdic acid is colorless and inodorous, fuses at 100.5° F., and solidifies to a radiated crystalline mass. It volatilizes without change at a higher temperature, does not oxidize in the air, and is readily soluble in alcohol and ether, but insoluble in water.

Erucic acid or brassic acid, $C_{22}H_{42}O_2 = C_{21}H_{41}.COOH$, occurs in the fatty oil of mustard seed, in colza oil and grape-seed oil. Lead plaster prepared from these oils is treated with ether, whereby lead erucate is left behind in an undissolved state. This is decomposed with alcohol and hydrochloric acid, and, after evaporating, the alcoholic solution separated from the lead chloride; the remaining acid is purified by recrystallization from alcohol.

Erucic acid crystallizes in long shining needles, fusing at 93.0° F. It is insoluble in water, but freely soluble in alcohol and ether. It absorbs oxygen from the air, and, like oleic acid, is converted by nitrous acid into an isomeric combination —*brassidic acid*—which fuses at 133° F.

By fusing erucic acid = *acetoarachic acid*, with potash, it is converted into arachic and acetic acids.

$$\underbrace{C_{21}H_{41}.COOH.}_{\text{Erucic acid}} + 2HOH = \underbrace{CH_3COOH}_{\text{Acetic acid}} + \underbrace{C_{19}H_{39}COOH}_{\text{Arachic acid.}}$$

The basic glyceride of erucic acid—*dierucine*, $C_{47}H_{88}O_7 = (C_{21}H_{41}COO)_2.OH.C_3H_5'''$, occurs in colza oil and fuses at 116.5° F.

Linoleic acid, $C_{16}H_{28}O_2 = C_{15}H_{27}COOH$.

	Atomic weight.	
16C	192	76.19 per cent.
28H	28	11.11 "
2O	16	12.70 "
1 molecule $C_{16}H_{28}O_2$	252	100.00

Linoleic acid occurs as glyceride in linseed oil, hemp seed oil, and very likely in all other drying oils. It has been very little studied.

It is isolated by saponifying linseed oil and poppy-seed oil. The resulting soap is treated with hot water and soda lye and purified by repeated washing. It is then dissolved in water and decomposed by calcium chloride, whereby the lime salts of the fatty acids present are precipitated. The precipitate is washed with water, pressed, and treated with ether, which only dissolves the calcium linoleate, the lime salts of the other fatty acids remaining in solution. The ethereal solution is decomposed with cold dilute hydrochloric acid, the calcium chloride passing into the aqueous solution, while the linoleic acid remains dissolved in the ether.

The dissolved linoleic acid is separated from the aqueous solution, and the ether distilled off in a current of hydrogen at as low a temperature as possible. The dark yellow linoleic acid which is left behind is, however, not pure, and has to be dissolved in alcohol and precipitated with ammonia and barium chloride as barium linoleate, This is washed, pressed and dissolved in ether, and the warts and grains shooting out from the solution are repeatedly recrystallized from ether. From the barium salt the linoleic acid is obtained by shaking with ether and dilute hydrochloric acid, lifting off the ethereal layer and distilling off the ether in a current of hydrogen. The acid remaining behind is dried under an air-pump over sulphuric acid and a mixture of lime and copperas, which absorbs any oxygen present.

Not entirely pure linoleic acid is obtained by the decomposition of the lead linoleate with sulphuretted hydrogen and extraction with ether.

Linoleic acid is a thinly fluid oil of a slightly yellow color, with a specific gravity of 0.9206 at 59° F. It possesses strong refractive power, and shows a slight acid reaction. It does not solidify at —0.4° F., and is insoluble in water, but freely soluble in alcohol and ether.

By standing in the air it absorbs oxygen with avidity, becomes thick and viscous, and is finally converted into a varnish-like mass. Thin layers of it upon wood, dry, on exposure to the air, to a varnish; upon glass it becomes only viscous.

By treating linoleic acid with hydriodic acid and amorphous phosphorus it is converted by the nascent hydrogen into stearic acid.

Linoleic acid does not volatilize without decomposing, and when distilled yields products different from those obtained from oleic acid; no sebacic acid is formed. Nitrous acid, or hyponitrous acid, renders linoleic acid viscous, but without separating crystals of elaïdic acid or of an allied acid. By the action of nitric acid a smeary resin is produced.

In the many investigations of linoleic acid by F. Möck, L. M. Norton, N. A. Richardson and especially by K. Hazura, it has been found that, like ricinoleic acid, linoleic acid is a mixture of various acids. Hazura included in his investigations the fluid fatty acids of *linseed oil*, *hemp seed oil*, *poppy oil*, *nut oil* and *cotton seed oil*, and established in them:

Linolic acid, $C_{18}H_{32}O_2 = C_{17}H_{31}.COOH$,

Linolinic acid and the isomeric *isolinolinic* acid, $C_{18}H_{30}O_2 = C_{17}H_{29}COOH$,

Oleic acid, $C_{18}H_{34}O_2 = C_{17}H_{33}.COOH$.

COMPOSITION OF LINOLEIC ACIDS.

Per cent. of fatty acids from	Linseed oil.	Hemp-seed oil.	Nut oil.	Poppy oil.	Cotton-seed oil.
Linolinic acid	15	15	13	5	—
Isolinolinic acid	65	15	—	—	—
Linolic acid	5	70	80	65	60
Oleic acid	15	15	7	30	40

These non-saturated fatty acids, when oxidized in their alkaline solutions with potassium permanganate, add up as many hydroxyl groups as they contain free equivalents, and give saturated oxyfatty acids with the same number of carbon-atoms in the molecule. Thus are formed from:

$$\left.\begin{array}{l}\text{Oleic acid}\\ \text{Elaïdic acid}\end{array}\right\} C_{18}H_{34}O_2 \quad \left.\begin{array}{l}\textit{Dioxystearic acid}\\ \textit{Isodioxystearic acid}\end{array}\right\} \begin{array}{c}C_{17}H_{33}(OH)_2\\ COOH\end{array}$$

$$\text{Linolic acid } C_{18}H_{32}O_2 \quad \textit{Tetraoxystearic acid } C_{17}H_{31}(OH)_4.COOH = \textit{sativic acid.}$$

$$\left.\begin{array}{l}\text{Linolinic acid}\\ \text{Isolinolinic acid}\end{array}\right\} C_{18}H_{30}O_2 \quad \left.\begin{array}{l}\textit{Hexoxystearic acid}\\ \textit{Isohexoxystearic acid}\end{array}\right\} = C_{17}H_{29}(HO)_6COOH =$$

Linusic acid, eventually *Isolinusic acid.*

In observing the process of drying, Hazura and Bauer found that these drying acids exhibit a similar behavior towards the oxygen of the air, the only difference being in the time required for oxidation, linolinic and isolinolinic acids drying most rapidly.

COMPOSITION OF THE OXYACIDS OF LINOLEIC ACIDS.

100 parts of fatty acids from	Linseed oil.	Hemp-seed oil.	Nut oil.	Poppy oil.	Cotton-seed oil.
Give when oxidized	Oxyfatty acids.				
Dioxystearic acid	1.2 p. c.	4.0 p. c.	2.5 p. c.	8.5 p. c.	23.0 p. c.
Sativic acid	6.5 "	24.0 "	25.0 "	18.5 "	31.5 "
Linusic acid .... Isolinusic acid	20.3 "	2.5 "	2.0 "	6.3 "	——

7. *Separation of the Fatty Acids, and Examination of the various Fatty Acids contained in a Fat or Oil.*

The separation of the different acids of the fatty acid series is an operation which frequently occurs in the laboratory.

With liquid volatile fatty acids the purpose can frequently be approximately effected by fractional distillation, *i. e.*, by collecting the portions of a distillate volatilizing at varying boiling points, and with solid fatty acids by crystallizations.

But with volatile fatty acids the separation is far more effectively accomplished by a partial saturation of the acid mixture with a base, and distilling off the portion not fixed; and with solid fatty acids, by fractional precipitation of the dissolved acids with a salt of the alkaline earths or lead. The former method was first successfully used by Liebig for the separation of such volatile fatty acids as butyric, valerianic, and acetic acids, while Heintz first employed fractional precipitation for the separation of solid fatty acids.

Separation of volatile fatty acids.—One-half of a mixture of valerianic, butyric, and acetic acids is saturated with sodium carbonate; the non-saturated half is then added and the mixture distilled. By this operation the acetic acid forces the valerianic and butyric acids from their sodium salts, and the valerianic acid the butyric acid from its sodium salt.

According to the quantity of the separate acids distilled, acetic acid being, for instance, present in greatest quantity, all the valerianic acid together with the butyric acid passes over, and even some acetic acid, while a so-called acid sodium acetate remains in the residue. If, however, butyric acid preponderates, the distillate contains first pure butyric acid, while sodium acetate and sodium valerate remains behind. By continued distillation, valerianic acid with some butyric acid passes over.

The remaining residue of sodium acetate with small quantities of sodium valerate is subjected to distillation with dilute sulphuric acid, the acetic acid being obtained in the distillate.

By repeating the operation several times with the acid mixture thus separated, the greater portion of the different acids can be obtained in a pure state, which is readily ascertained by determining the boiling point by passing a thermometer into the distilling apparatus.

The manner of examining other mixtures,. for instance, propionic, butyric, caproic, caprylic acids, is effected in the same way. The fatty acid with the greater content of carbon and higher fusing point drives out the fatty acid with the smaller content of carbon and lower boiling point, acetic acid being, however, an exception. This behavior of the fatty acids is due, on the one hand, to the stronger affinity to the base used, and, on the other, to the action of the higher temperature on the strength of the affinity.

Separation of solid fatty acids.—The separation of the different solid fatty acids is effected, according to Heintz, as follows:

The mixture of acids to be separated is dissolved in so large a quantity of boiling alcohol that no fatty acid can separate even on cooling to 32° F. To the hot alcoholic solution is added, drop by drop, sufficient of a hot alcoholic solution of sugar of lead to fix only about one-half of the acids on lead oxide.

If a sufficient quantity of alcohol has been used, the boiling fluid remains clear even after the addition of the sugar of lead. The slightest cooling renders it, however, turbid, and after complete cooling, all the lead oxide combined with about one-half of the fatty acids is precipitated.

Should a precipitate be already formed at the boiling heat, too little alcohol has been used, and it is best to add then a few drops of acetic acid, instead of alcohol, which effects a ready solution of the separated lead.

The precipitate is filtered and washed with alcohol until the filtrate is no longer rendered turbid by water.

To separate the fatty acid from this lead salt, it is taken from the filter while saturated with alcohol, mixed with alcoholic hydrochloric acid and boiled for a short time. The lead chloride formed separates completely in the cold, while the fatty acid remains dissolved in the alcohol. The solution still contains, however, small quantities of the ethyl combinations of the fatty acids formed by boiling with alcoholic hydrochloric acid. To destroy these, the alcoholic fluid is boiled for some time with an excess of caustic potash, after which water is added and the greater portion of the alcohol evaporated by distillation. From this soap solution the fatty acid is then to be separated by hydrochloric acid.

The portion of the fatty acids, which by the above precipitation with sugar of lead remains unaltered in the filtered alcoholic solution, is then precipitated by a slight excess of an alcoholic solution of sugar of lead, and the fatty acid separated from this precipitate in the same manner as above.

The separation of two fatty acids effected in the above manner is not absolutely complete; it is, however, sufficient to subject them to strong pressure instead of washing, and then treat the lead salts, as stated, by boiling with alcoholic hydrochloric acid, and to decompose the alcoholic solution with caustic potash, and later on with hydrochloric acid.

The boiling points of the two portions of acid must be determined. If they are nearly alike, and there is no essential difference in their physical properties, it may be safely assumed that the substance under examination is not a mixture of various fatty acids, but consists essentially of only one, which may possibly have been contaminated by a small quantity of another fatty acid. In this case both portions are combined and the acid is purified by crystallization from alcohol, repeated several times, if necessary.

If, however, there is an essential difference in the melting points of the two portions of acid and also in their physical properties, they are again subjected to the same process of separation, which is repeated until the physical properties are nearly alike. The portions finally obtained are again united and crystallized from alcohol. They are then subjected to a further examination to determine their nature.

Three or more fatty acids in a mixture can also be separated by this method by repeated treatment of not only the most extreme portions, which contain the strongest and weakest acid, but also the medium ones.

In case one of the separated acids assumes a beautiful crystalline structure in passing from the liquid into the solid state, it is not necessary to execute the separation with this portion in the manner described, as it can generally be obtained perfectly pure by crystallizing it once or twice from an alcoholic solution.

For such fractional precipitations of mixed fatty acids, barium acetate or magnesium acetate may be used instead of sugar of lead; in fact, magnesium acetate deserves frequently the preference.

For the separation, for instance, of stearic and palmitic acids (the mixture which was formerly termed margaric acid), add to the hot alcoholic solution one-seventh of its quantity of magnesium acetate; in the precipitate stearic acid, which forms the most insoluble salt with magnesium, is contained in a preponderating quantity. If the filtrate is again mixed with a quantity of magnesium acetate not nearly sufficient for complete precipitation, the result will be a precipitate containing palmitic acid; while the precipitate obtained by the third operation, executed in the same manner, will contain still more palmitic acid, and so on.

The precipitates are decomposed with hydrochloric or sulphuric acid, and the separated fatty acids of each single precipitate, if found to be mixed substances, subjected to the same treatment.

Oleic acid is readily separated from the fatty acids. After precipitating the mixture with lead acetate and purifying it by washing with alcohol and then treating with ether, the lead oleate is completely dissolved, while lead palmitate and lead stearate remain in solution.

The decomposition of the lead salts is effected in the known manner.

Another method of separating the oleic acid from the stearic and palmitic acids is based upon the insolubility of the last two acids in a mixture of 30 volumes of alcohol and 22 volumes of acetic acid, in which oleic acid is completely soluble.

By evaporating the mixture of alcohol, acetic acid, and oleic acid, the latter remains behind and is purified by saponification with alkalies and re-separation by means of an acid.

The separation of the remaining palmitic and stearic acids is effected by the above-described process.

Examination of the Various Fatty Acids Contained in a Fat or Oil.

For the examination of the various fatty acids contained in a fat or oil, their mechanical separation must first be effected, *i. e.*, the solid glycerides, palmitin, stearin, etc., have to be separated from the liquid glycerides, olein, etc.

The solid fats, tallow, etc., can be pressed off at once, but the softer fats, goose-grease, laurel butter, butter, etc., must first be exposed to a sufficiently low temperature to allow of the better solidification of the more solid constituents, and the fat oils cooled down to the freezing point.

Pressing off is best effected in flannel, and gradually, so as to give the fluid portion time to run off.

Both the fluid portion and the solid portion remaining in the press cloth are saponified, each by itself. By saponification, for which only dilute alkaline lyes should be used, stearin and palmitin are more quickly decomposed than olein. If, therefore, by the saponification of the fluid part of the fat or oil the portion difficult to saponify is pressed off and further saponified by itself, a still more complete separation of the oleic acid from the small quantities of palmitic acid, stearic acid, etc., always present in the fluid portion, is effected. Saponification is facilitated and promoted by the addition of some alcohol, the foaming of the fluid being thereby prevented. In case the surface of the fluid, when at rest, should show drops of fat, more alcohol will have to be added. Saponification is complete in ten to fifteen minutes.

The warm soap solution is decomposed with sulphuric or tartaric acid; the glycerin and fluid volatile acids pass into the aqueous solution; while the solid fatty acids, together with the oleic acid, etc., float on top.

The aqueous solution is saturated with a salt, for instance, sodium sulphate (Glauber's salt), and subjected to distillation. The distillate contains the volatile fatty acids, which, after a partial saturation with sodium carbonate, are separated by fractional distillation.

The solid residue obtained by the decomposition of the soap solution is first separated by pressure into a liquid and solid portion; the further operations required will be understood from what has been already said.

CHAPTER VII.

GENERAL TESTS FOR DETERMINING THE PURITY OF OILS.

IN speaking of the general physical properties: color, odor, taste, specific gravity, consistency, freezing point, fusing point, solidifying point, as well as of the more particular physical properties: viscosity, inflammability, refraction, spectrum phenomena, polarization, electrical conductivity, the methods for their determination have been given. We have now to deal with physico-chemical examinations which are dependent on the action of chemical reagents, while the physical phenomena and examinations, such as the determination of the specific gravity and of the fatty acids separated at a higher temperature, are only complementary to the chemical tests.

So-called *qualitative* methods—*chromatic or color test, elaïdin test, thermal test, cohesion test*—were formerly exclusively used for recognizing the purity of oils, while at the present time more stress is laid upon *quantitative methods—determination of the saponification number of the volatile and non-volatile fatty acids, determination of the quantities of iodine* which fats or fatty acids are capable of absorbing; nevertheless the examinations according to the first method should not be abandoned. To the qualitative methods belong also the *determination of the specific gravity of oils, etc., at a higher temperature, solubility in alcohol, glacial acetic acid, etc.*

A. *Qualitative Examinations.*

1. *Chromatic or color test.*—The object of this test is the production of the characteristic color-phenomena which oils show with various chemical reagents, especially with concentrated mineral acids or mixtures of them. In refined oils the colors appear less intense, *i. e.*, with a paler tone.

Oils extracted with ether and petroleum-ether also show the colorations to a less extent than expressed oils.

Of the reagents used,

NITRIC ACID of 1.18 to 1.20 specific gravity, mixed with equal parts of oil, gives the following colors:

Yellowish: beech-nut oil, castor oil, neat's-foot oil, white mustard oil.

Yellow: niger oil, hazel-nut oil, linseed oil, nut oil.

Reddish-yellow: almond oil, maize oil, peach-kernel oil, peanut oil.

Yellow-red: sesamé oil.

Brownish-yellow: black mustard oil.

Brick-red: German sesamé or camelina oil.

Red: seal oil.

Greenish: hemp oil, olive oil, wild radish seed oil.

Greenish-yellow: crude colza oil.

The colors will appear still more plainly if the nitric acid contains a trace of nitrous acid.

INDIFFERENT TOWARDS NITRIC ACID, are Brazil-nut or Para nut oil, candle-nut oil, refined colza oil, cotton-seed oil, radish-seed oil, sunflower oil.

Fish, liver, seal, and whale oils are but little changed.

FUMING NITRIC ACID of 1.40 to 1.45 specific gravity exerts a very energetic influence upon many oils; great care is therefore to be exercised. Add 8 to 12 drops of the acid to 30 to 40 drops of oil and shake immediately. It is also frequently of great advantage to observe the colored zone formed by carefully allowing the acid to run down on the side of the test-tube without mixing with the oil. The following colorations take place:—

Yellow: Brazil-nut or Para nut oil, castor oil.

Red-yellow: candle-nut oil, guizot or niger oil, peanut oil.

Yellow-red: poppy oil.

Green: hemp seed oil.

Blue-green: hazel-nut oil.

Red: black mustard oil (reddish), nut oil, peach-kernel oil, radish-seed oil.

Cherry-red: linseed oil, liver oil, white mustard-seed oil.

Brown: colza oil, cotton-seed oil (orange), fish oil, sesamé oil, hemp oil, madia oil (red-brown), maize oil (dark), neat's-foot oil, olive oil, seal oil (red), sunflower oil (reddish), whale oil (black).

SULPHURIC ACID of varying concentration is used, that of 1.60 to 1.70 specific gravity = 10 parts acid of 1.840 specific gravity and 4 parts water, being best adapted for the purpose. With acid of greater concentration the transitions take place too quickly, in consequence of carbonization. The test is to be executed in a small porcelain dish, stirring constantly with a glass rod. For 15 drops of oil, 5 drops of acid are used. For the better observation of the gradually appearing color phenomena it is advisable to dilute the oil somewhat with ether, carbon disulphide, or benzine.

Yellow: candle-nut oil.

Green: black mustard oil (blue), fish oil, sesamé oil, niger oil (gray), hazel-nut oil (blue), hemp oil, madia oil, maize oil, olive oil, sunflower oil (bluish).

Olive-green: almond oil, peach-kernel oil.

Green-brown: colza oil, poppy oil, radish oil, white mustard oil.

Brown: neat's-foot oil, nut oil, peanut oil.

Black-brown: whale oil.

Red: beech-nut oil, Brazil-nut or Para-nut oil, cotton-seed oil (purple), German sesamé or camelina oil.

Red brown: seal oil (blood like).

Violet: liver oil.

A MIXTURE OF SULPHURIC AND NITRIC ACIDS, composed of equal parts of the concentrated acids, or, for a more gradual reaction, of equal parts of water and of these acids, produces, on shaking with an equal volume of oil, the following colors and shades of these colors:

Yellow: castor oil, nut oil (brown), radish-seed oil (gray).

Reddish-yellow: almond oil, colza oil (crude and refined), maize oil, peanut oil, white mustard oil.

Green: sesamé oil (later on yellow-red), hazel-nut oil (blue), hemp oil (finally black), olive oil.

Red: beech-nut oil (slightly), cotton-seed oil, German sesamé or camelina oil (brown), peach oil (peach), poppy oil (brick).

Brown: candle-nut oil (red), fish oil, niger oil, linseed oil (dark, first green), liver oil (red), madia oil, neat's-foot oil, seal oil, sunflower oil, whale oil (dirty), wild radish-seed oil.

Black: hemp oil (first green).

POTASH OR SODA LYE of 1.33 specific gravity gives, on shaking 3 volumes of oil with 1 volume of lye; the following emulsions:

White: Brazil-nut or Para nut oil, castor oil, colza oil, sesamé oil, neat's-foot oil, nut oil, olive oil, sunflower oil.

Gray-white: almond oil, peach-kernel oil.

Yellowish: beech-nut oil, black mustard oil, candle-nut oil, hazel-nut oil, hemp oil, madia oil, maize oil, poppy oil, radish-seed oil, white mustard oil.

Yellow: German sesamé or camelina oil, linseed oil.

Flesh color: peanut oil.

Violet: crude cotton-seed oil (on the surface after standing).

Red: fish-oil, liver oil, seal oil, whale oil.

Greenish: wild radish seed oil.

Reddish—dark red: train oils.

SOLUTION OF ZINC CHLORIDE.—Mix equal parts of the solution and oil in a small saucer with a glass rod. The colors appear either immediately or after standing. A solution of the consistency of syrup, formed by the deliquescence of the dry zinc chloride in the air, is best adapted for the purpose. The following colorations are produced:

White: almond oil, castor oil, peach-kernel oil.

Green: black mustard oil (gray), crude colza oil, German sesamé or camelina oil, niger oil, hazel-nut oil, hemp oil (yellow), linseed oil (pale), maize oil (yellow), radish-seed oil, white mustard oil (brownish).

Brown: cotton-seed oil, peanut oil (pale).

Red: beech-nut oil (flesh color), Brazil-nut or Para nut oil (rose), olive oil (table oil, slightly rose).

INDIFFERENT TOWARDS ZINC CHLORIDE are candle-nut oil, sesamé oil, linseed oil, madia oil, neat's-foot oil, nut oil, poppy oil, sunflower oil, and all train oils.

HYDROCHLORIC ACID.—Mix equal parts (about 1 cubic centimeter of each) of acid of specific gravity 1.125 and oil, and add to the mixture a small portion (about 1 gramme) of cane sugar. The following colorations are produced after *clearing of the acid:*

Yellow: almond oil (orange), castor oil (orange), cottonseed oil (orange), linseed oil, olive oil, peanut oil (very intense).

Green: black mustard oil (slightly), hemp oil (yellow).

Brown: crude colza oil (very strong), liver oil, peach-kernel oil, poppy oil (pale).

Gray: raddish-seed oil.

Violet: sesamé oil.

INDIFFERENT TOWARDS HYDROCHLORIC ACID are beech-nut oil, candle-nut oil, German sesamé or camelina oil, niger oil, madia oil, maize oil, neat's-foot oil, poppy oil, raddish-seed oil, sunflower oil, white mustard oil.

• The coloration of the hydrochloric acid sometimes appears in a short time, or only after 3 to 4 hours. In 8 hours a slight brownish sugar color appears.

PHOSPHORIC ACID (SYRUPY), 5 parts acid = 1.120 specific gravity evaporated to 1 part gives in the proportion of 1 : 5 volumes of oil a very characteristic red coloration for train oil, which later on passes into black.

CHLORINE in the form of gas introduced into train oils colors them black, while it bleaches most other oils.

SOLUTION OF SUBACETATE OF LEAD (GOULARD'S EXTRACT); LEAD PLASTER. Many oils of cruciferous plants, especially colza and mustard oils, when heated with lead plaster, impart to the latter a brown to black coloration in consequence of the formation of lead sulphide from a sulphur combination contained in these oils. The presence of sulphur in these oils may also be established by the addition, after saponification, of solution of subacetate of lead, or immersing a slip of paper saturated with the solution; blacking is due to lead sulphide formed. *Cold pressed colza oils are free from sulphur.*

Oils extracted with carbon disulphide occasionally contain carbon disulphide, the presence of which, according to O. Braun, may be established by simple saponification. 60 grammes of oil are stirred together with 30 grammes of lye of 40° Bé = 1.3846 specific gravity, and the resulting soap allowed to stand in a warm place for one hour. With oil badly purified, the soap becomes dark green and acquires a bad odor.

NITRATE OF SILVER SOLUTION. A solution of 2 parts nitrate of silver, 10 parts water, and 88 parts alcohol, is more or less reduced by some oils and produces a *brown-red*, *dark-red*, or *black* coloration in the oils of *cotton seed*, *bitter almond*, *hemp seed*, *wild radish seed*, *neat's foot*, *linseed*, *peach-kernel* and *colza*. Indifferent towards the solution are: *Oils of beechnut*, *castor*, *mustard*, *olive*, *peanut*, *sesamé*, *sweet almonds*.

In colza and mustard oils silver sulphide is also formed.

The test is executed as follows: 5 volumes of oil and 1 volume of the nitrate of silver solution in a test tube are gradually heated to boiling. The reduction takes place in a short time, but with bitter almond and peach-kernel oils only after standing for some time. A longer period is also required for the reaction when 5 volumes of the oil to be examined are diluted with the same quantity of ether and 1 volume of the nitrate of silver solution is added. The test tube in this case is closed with a cork and allowed to stand.

TABLE OF CHROMATIC (COLOR) REACTIONS.

Name of Oil.	Nitric Acid.	Fuming Nitric Acid.	Elaïdin Test, Time of Solidifying.	Sulphuric Acid.
Almond oil	reddish-yellow,	reddish,	24 hours,	olive-green.
Beech-nut oil	yellowish,	yellow-red,	26 "	red.
Black mustard oil	brownish-yellow,	reddish,	18 "	blue-green.
Brazil-nut or Para-nut oil	—	yellow,	½ hour,	red-brown.
Candle-nut oil	—	red-yellow,	—	yellow.
Castor oil	yellowish,	yellow,	6 to 7 hours,	red-yellow.
Colza oil (refined)	—	brown-red,	20 "	green-brown.
Colza oil (crude)	—	brown-red,	20 "	dirty green-brown.
Cotton-seed oil	—	orange-brown,	20 to 24 "	purple.
Fish oils	—	brown,	—	greenish.
German sesamé or camelina oil	brick-red,	dirty brown-red,	—	orange.
Gingelly or sesamé oil	yellow-red.	reddish-brown,	20 to 24 "	green,
Guizot or niger oil	egg-yellow,	reddish-yellow,	—	gray-green.
Hazel-nut oil	yellow,	blue-green,	2 to 3 "	blue-green.
Hemp-seed oil	greenish-yellow,	dark brown-red,	—	green.
Linseed oil	cadmium-yellow.	cherry-brown,	—	green.
Liver oils	—	blood-red—blue-red,	—	violet,
Madia oil	—	brown-red,	—	gray-green.
Maize oil	red-yellow,	brown,	24 to 25 "	dark green.
Neat's-foot oil	yellowish,	brown-yellow,	12 "	brown.
Nut oil	yellow,	dark red,	—	brown.
Olive oil (table)	pale green,	dirty brownish,	1 to 2 "	greenish.
Olive oil (common)	greenish,	dirty brownish,	1 to 2 "	green.
Peach-kernel oil	reddish-yellow,	peach-blossom red,	20 "	olive-green.
Peanut oil	reddish-yellow,	red-yellow,	24 to 30 "	brown.
Poppy oil	—	yellow-red,	—	green-brown.
Radish-seed oil	—	red,	24 "	greenish-brown.
Seal oils	—	red-brown,	—	brown-red (blood-like).
Sunflower oil	—	reddish-brown,	—	bluish-green.
Whale oils	—	black-brown,	—	black-brown.
White mustard oil	yellowish,	cherry-red,	20 "	greenish-brown.

TABLE OF CHROMATIC (COLOR) REACTIONS.

Name of Oils.	Mixture of Sulphuric and Nitric Acids.	Potash or Soda Lye.	Zinc Chloride.	Hydrochloric Acid and Sugar.
Almond oil	reddish,	gray-white,	white,	orange-yellow.
Beech-nut oil	reddish,	yellowish,	flesh color,	—
Black mustard oil	greenish-yellow,	white-yellow,	gray-green,	greenish.
Brazil-nut or Para-nut oil	brownish-yellow,	white.	rose-red,	brownish,
Candle-nut oil	red-brown,	yellowish,	—	—
Castor oil	yellow,	white,	white,	yellow-orange.
Colza oil (refined)	reddish-yellow,	white,	yellowish,	brown.
" (crude)	reddish-yellow,	yellowish,	blue-green,	brown.
Cotton-seed oil	red,	surface violet,	brown,	yellow-orange.
Fish oil	brown,	red,	—	—
German sesamé oil, or Camelina oil	brownish-red,	yellow,	green,	—
Gingelly oil, or sesamé oil	green,	whitish,	—	violet.
Guizot, or niger oil	brown,	white,	slightly green,	yellowish.
Hazel-nut oil	blue-greenish,	yellowish,	gray-green,	—
Hemp oil	finally black,	greenish-yellow,	yellow-green,	yellow-greenish.
Linseed oil	green-brown,	yellow,	—	yellow.
Liver oil	red-brown,	red,	—	brown.
Madia oil	dirty brownish,	yellowish,	—	—
Maize oil	red-yellow,	yellowish,	yellow-green,	—
Neat's foot oil	brown,	white,	—	—
Nut oil	brown-yellow,	yellowish-white,	—	—
Olive oil (table)	greenish,	white,	slightly rose color,	yellow-orange.
" (common)	green,	dirty white,	greenish,	brownish.
Peach-kernel oil	peach-blossom red,	gray-white,	white,	yellow-orange.
Peanut oil	reddish-yellow,	flesh color,	brown,	yellow.
Poppy oil	brick-red,	yellowish,	—	pale-brown.
Radish-seed oil	gray-yellow,	yellowish,	gray-greenish,	gray.
Seal oils	reddish-brown,	red,	—	—
Sunflower oil	dirty-brownish,	white,	—	—
Whale oils	dirty brown,	red,	—	reddish.
White mustard oil	reddish-yellow,	yellowish,	brownish-green,	—

2. *Elaïdin test.* This test is based upon the conversion of olein into elaïdin by the action of nitrous acid, and serves for distinguishing drying from non-drying oils, the latter forming solid masses, while oils such as cotton seed, beech nut, sunflower, etc., which stand between drying and non-drying oils, become only butter-like or pasty. By observing the time required for solidification and the color of the solid mass, an opportunity is also offered for testing the purity of the oils, for instance olive oil, almond oil, etc.

The elaïdin test is executed as follows: Mix in a test tube by occasional vigorous shaking 10 volumes oil, 1 volume water, and 2 volumes fuming nitric acid of specific gravity 1.45. After some time carefully add to the mixture saturated potassium nitrite solution by allowing it to run down on the wall of the tube, and observe the time of solidification.

Poutet's method of executing the elaïdin test is as follows: 10 grammes oil, 5 grammes nitric acid of 40 to 42° Bé. and 1 gramme mercury are brought into a test-tube and the mercury dissolved by vigorous shaking for 3 minutes. The whole is then allowed to stand 20 minutes, when it is again shaken for 1 minute. From this period on, oils, in tests made in the Paris Municipal Laboratory, exhibited the following behavior:

Olive oil	solidified	in	1	hour	—	minutes.
Peanut oil	“	“	1	“	20	“
Sesamé oil	“	“	3	“	5	“
Colza oil	“	“	3	“	5	“
Sheep's trotter oil	“	“	2	“	—	“

Linseed oil formed a red, pasty foam.

Cod-liver oil became pasty, red and foamy.

Whale oil behaved in the same manner.

Hemp-seed oil remained unchanged.

Copper may be substituted for the mercury. For example 10 cubic centimeters of oil are brought into a test-tube together with 10 cubic centimeters of 25 per cent. nitric acid and 1 gramme of copper wire, and allowed to stand.

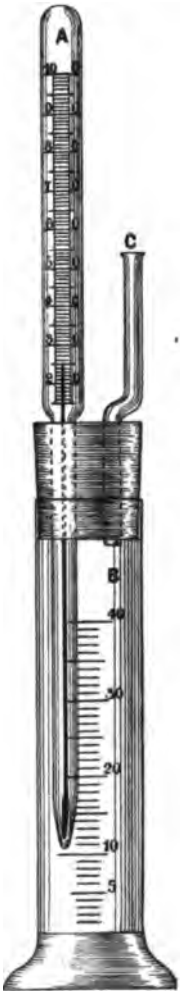
Other analysts conduct into the sample of oil, floating upon a small quantity of water, the *red vapors* evolved on treating iron with nitric acid.

3. *Thermal test.* By the *thermal oil test of Maumené–Fehling*, the degree of heating is determined which takes place on mixing fat oils with concentrated sulphuric acid of 66° Bé. = 1.840 specific gravity Drying oils are thereby more strongly heated than non-drying oils, but oils of the same group also show considerable variations.

For the application of the test the same conditions should always prevail, *i. e.*, the same initial temperature, size of the vessel, quantities of acid and oil, etc.

The *thermal oil-tester* shown in Fig. 33 is very suitable for the purpose. A graduated cylinder, B, is provided with an India-rubber stopper, through which passes the stem of a thermometer, *A*, so graduated that the divisions are all above the stopper; a short piece of tubing also passes through the stopper, serving as a vent. 25 cubic centimeters of oil are run into the cylinder, and then 5 cubic centimeters of sulphuric acid, the latter by means of a pipette, applied to the side of the cylinder, so that the acid falls to the bottom without mixing with the oil. The stopper and thermometer being inserted and the temperature taken, the end of *C* is closed by the finger, and the whole shaken for a few seconds. The finger is then immediately removed from *C* and the thermometer watched so as to mark the highest point to which it rises, and hence the range through which

FIG. 33.



THERMAL OIL-TESTER.
A, thermometer;
B, graduated cylinder;
C, vent-tube.

the chemical action has heated the mass. Of great importance is the exact specific gravity of 1.840 = 66° Bé. of the acid used, which is prepared by mixing 80 volumes concentrated sulphuric acid and 20 volumes fuming sulphuric acid.

The appended table, published by Allen, gives the rise in the temperatures of oils with sulphuric acid, as noted by various observers:

TABLE SHOWING THE RISE IN THE TEMPERATURES OF FAT OILS WHEN MIXED WITH SULPHURIC ACID.

OILS.	Increase in temperature with sulphuric acid ° C.				
	Maumené.	Baynes.	Dobb.	Archbutt.	Allen.
Olive oil	42	40	39–43	41–45	41–43
Almond oil.	52–54	35	—	—	—
Colza oils	57–58	60–92	54–60	55–64	51–60
Peanut oil	67	—	—	47–60	—
Beechnut oil	65	—	—	—	—
Sesamé oil	68	—	—	65	—
Cottonseed oil, crude	—	84	61	70	67–69
" refined	—	77	—	75–76 86–88	74–75
Poppy oil	74	—	—		—
Niger oil	—	82	—	—	81
Hemp-seed oil	98	—	—	—	—
Nut oil	101	—	—	—	—
Linseed oil	103	104–124	—	—	104–111
Cocoanut-olein	—	—	—	—	26-27
Castor oil	47	—	—	46	—
Lard oil	—	—	—	—	41
Tallow oil	41–44	—	—	—	—
Neat's-foot oil	—	—	—	43	—
Horse-foot oil	51	—	—	—	—
Whale oil, from the North	—	—	—	—	91
" from the South	—	—	85–86	92	—
Porpoise oil	—	—	—	—	50
Seal oil	—	—	—	—	92
African fish oil	—	—	156	—	—
Shark liver oil	—	—	—	—	90
Cod-liver oil	102–103	116	—	—	113
Menhaden oil	—	—	—	123–128	126
Spermaceti oil	—	—	—	51	45–47
Dolphin oil	—	—	—	42	41–47
Oleic acid	—	—	—	37.5	38.5

For the application of Maumené's test, Jean* has constructed a special apparatus, termed by him "*thermeleometer.*" The oil holder *A*, Fig. 34, is 4 centimeters in diameter, 6 centimeters high, and at 15 cubic centimeters is provided with a mark. In the acid holder *B* is ground in the stopper *C*, to which is fused a tube with a piece of rubber tubing, *F*, attached. *T* is a thermometer clamped to *B*. 15 cubic centimeters of oil previously heated to from 104° to 122° F., are brought into *A* and 5 cubic centimeters of sulphuric acid of 65° Bé. into *B*. *B* is then placed in *A*, stirring at the same time with the thermometer until the temperature indicates exactly 86° F. The apparatus is then placed in the felt-lined, brass case *E*, the acid is forced from *B* into *A* by blowing through the rubber tubing *F*, and stirring continued until the maximum temperature is reached. A table for genuine oils may be made for general use. With old oils yielding different numbers the "heating degree" of the fatty acids is determined at an initial temperature of 86° F. Drying oils are mixed with 5 cubic centimeters mineral oil.

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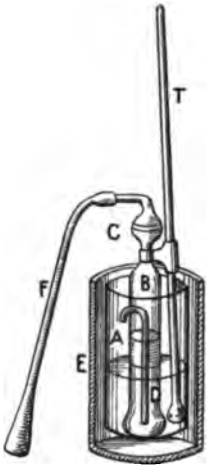
* Chem. Zeit., 1889. Rep. 306.

FIG. 34.



JEAN'S THERMELEOMETER.
A, oil-holder; *B*, acid-holder; *C*, stopper; *F*, rubber tubing; *E*, felt-lined case.

Jean found the following heating degrees:

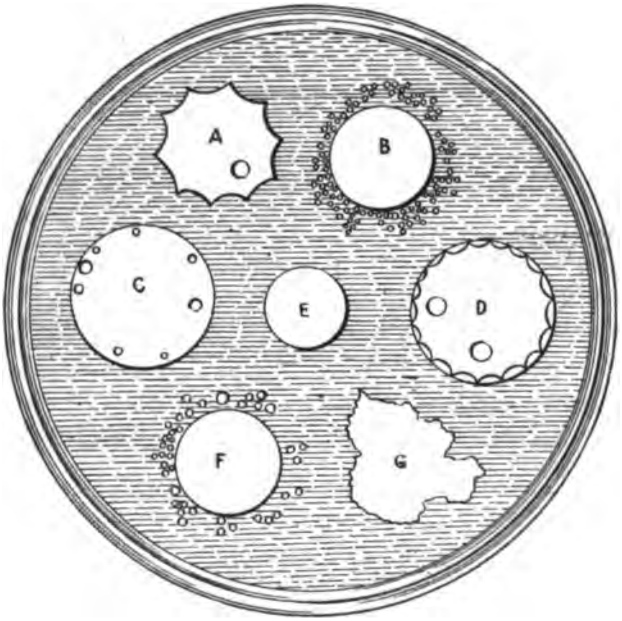
		Fatty acids.
Olive oil	106.7° F.	113° F.
Linseed oil	141.8° F.	228.2° F.
Colza oil, French	98.6° F.	111.2° F.
" Indian	98.6° F.	111.2° F.

In many cases, Maumené's test may serve for ascertaining the purity of an oil, or for making comparisons regarding the degree of drying.

4. *Cohesion test.* This method, introduced by Tomlinson, in 1864, is based upon physical principles, but is of value only

after many time-consuming observations. If by means of a glass rod a drop of oil is allowed to fall carefully upon the perfectly quiet surface of distilled water in a basin, a counter action of several forces takes place the moment the drop spreads out upon the surface, adhesion endeavoring to spread the drop as a thin film upon the surface, while cohesion seeks to prevent it. The result of these two forces forms the *cohesion figure*, and

FIG. 35.



COHESION FIGURES OF OILS.
A, colza oil; *B*, rape oil; *C D*, poppy oil; *E*, sesamé oil; *F*, peanut oil; *G*, olive oil.

it is claimed that the particular forms assumed by films of various kinds are sufficiently well defined and characteristic to be of service in detecting adulterations. Fig. 35 exhibits the different cohesion figures assumed by some oils. The drops give at first peculiar smooth-edged, circular iridescent disks; however, scallops and indentations are soon formed, or minute portions detached.

B. *Quantitative Examinations.*

Quantitative examinations of fats and oils require the determination of the content:

1. *Of all the fatty acids. Saponification number; Köttstorfer's number.*
    a. Ester number = Content of neutral fat.
    b. Acid number = Content of free acids.
2. *Of the solid fatty acids. Hehner's number.*
3. *Of the volatile fatty acids. Reichert's number.*
4. *Of the fatty acids of the non-saturated hydrocarbons. Iodine number; Hübl's number.*
5. *Of the oxyfatty acids. Acetyl number.*

1. *Determination of the Saponification Number.—Köttstorfer's Number.*

a. Ester number. For saponification each molecule fatty acid glyceride = ester or neutral fat, requires 3 molecules alkali. Since there is a difference in the molecular weights of the triglycerides, varying quantities of caustic alkali have been used: the greater the molecular weights of the glycerides or fatty acids, the less alkali will be requisite.

The *ester number* indicates how many milligrammes potassium hydroxide, KOH, are required by 1 gramme neutral fat for complete saponification. For the execution of the test an alcoholic semi-normal standard potash solution and semi-normal standard hydrochloric acid are required.

According to Köttstorfer, 1 or 2 grammes of filtered oil, or of fat purified by melting and filtering, together with 25 cubic centimeters of standard potash solution, are brought into a wide-necked flask of about 70 cubic centimeters capacity. The whole is then heated in a water bath for 10 to 20 minutes—cocoanut oil only 12 minutes—and gently agitated at intervals, until complete solution has taken place; after a few minutes more heating to ensure that saponification is complete, the resulting soap-paste is mixed with 5 drops phenolphthalein solution (1 phenolphthalein to 100 alcohol) and the unneutralized alkali titrated by semi-normal standard hydrochloric acid. The value of unneutralized alkali thereby determined is deducted from the original 25 cubic centimeters used, the remainder having been consumed for the saponification of the quantity of oil or fat employed.

The semi-normal potash solution is prepared by dissolving 28 grammes of pure potassium hydroxide, KOH = 56, in pure 96 per cent. spirit of wine = 0.832 specific gravity at 59° F. and filling the flask up to the liter mark. In consequence of the oxidation of spirit of wine, etc., the solution is not very durable, and its standard has to be determined each time, before use, with semi-normal hydrochloric acid. For this purpose 25 cubic centimeters of the alcoholic potash solution are heated on a water-bath for 10 to 15 minutes until commencement of boiling, and later on titrated, after adding phenolphthalein, with semi-normal hydrochloric acid, and this standard used for calculation. The difference between the non-heated and heated potash solution amounts to about $\frac{1}{20}$ cubic centimeter of the semi-normal hydrochloric acid. The potash solution must be measured exactly at 59 ° F.

According to the quantity of fat or oil used, the quantities of potassium hydroxide consumed are to be calculated to 1 gramme fat. 1 cubic centimeter semi-normal potash solution = 0.280 gramme KOH = 280 milligrammes.

Becker * recommends the use of an aqueous normal potash solution in place of the alcoholic semi-normal potash solution, and to saponify 1 or 2 grammes of fat with 10 cubic centimeters of normal potash solution and 50 cubic centimeters of commercial absolute alcohol.

Example. 1.532 grammes of olive oil have been saponified with 25 cubic centimeters alcoholic potash solution, and 12.7 cubic centimeters of hydrochloric acid have been used for titrating back. 25 cubic centimeters alcoholic potash solution = 22.5 cubic centimeters hydrochloric acid. 1 cubic centimeter hydrochloric acid = 0.0301 gramme potassium hydroxide.

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* Corresp. Blatt d. Ver. analyt. Chemiker, 2, 57.

Hence for saponification the 22.5 — 12.7 = 9.8 cubic centimeters of hydrochloric acid consume equivalent quantities of potassium hydroxide, *i. e.*, 9.8 × 0.0301 grammes = 294.9 milligrammes for 1.532 grammes of oil, or 294.9 : 1.532 = 192.5 milligrammes potassium hydroxide for 1 gramme of oil. Hence the saponification number of the oil examined is 192.5.

Instead of the saponification number Allen proposes to give the *saponification equivalent*, *i. e.*, the quantity of fat saponifiable by 1 equivalent or 56.1 parts potassium hydroxide. This number is obtained by dividing 5610 by the saponification number. However, this mode of calculation offers no advantage.

ESTER NUMBERS OF THE GLYCERIDES.

Triglycerides.	Formula.	Molecular weights.	Sodium hydroxide, 3NaOH.	Potassium hydroxide, 3KOH.	100 parts glyceride require		Ester number.
					NaOH. Parts.	KOH. Parts.	
Butyrin	$C_{15}H_{26}O_6$	302	120	168	39.73	55.60	556.00
Caprin	$C_{33}H_{62}O_6$	552			21.74	30.43	304.30
Caproin	$C_{21}H_{38}O_6$	384			31.25	43.78	437.80
Laurin	$C_{39}H_{74}O_6$	638			18.77	26.31	263.20
Linolein	$C_{57}H_{98}O_6$	878			13.68	19.12	191.20
(Margarin)	$C_{54}H_{99}O_6$	843			14.23	19.90	199.00
Myristin	$CH_{4586}O_6$	722			16.60	23.26	232.60
Olein	$C_{57}H_{104}O_6$	884			13.57	19.00	190.00
Palmatin	$C_{51}H_{98}O_6$	806			14.88	20.84	208.40
Ricinolein	$C_{57}H_{104}O_6$	932			12.86	18.02	108.20
Stearin	$C_{57}H_{110}O_6$	890			13.48	18.87	188.70

b. *Determination of the acid number.* Many fats contain free fatty acids, and besides those referred to on p. 112, there may be mentioned becuiba tallow, nutmeg butter, chaulmoogra oil, etc. Many oils, however, also contain free fatty acids and a certain, though not too high, content of them seems to be requisite for the agreeable taste of table oils. Each molecule of fatty acid requires for neutralization or saponification 1 molecule of potassium or sodium hydroxide, the saponification number, in this case called *acid number*, being the lower the higher the molecule weight of the fatty acid is. The *acid number* indicates how many milligrammes of potassium hydroxide are consumed for free acids in 1 gramme of fat.

For the determination of the free acid 5 to 10 grammes of the fat carefully melted and filtered are weighed up in a flask of 50 cubic centimeters capacity and mixed with sufficient of a mixture of ether and alcohol—20 parts ether, 5 parts alcohol—for the solution of the fat. Since commercial ether generally shows an acid reaction, it is, before using it for solution, mixed with a few drops of phenolphthalein solution, and then, drop by drop, with alcoholic potash solution until a constant rose-color appears; or the mixture is for some time agitated with calcined magnesia and filtered. The ethereal solution of fat is then titrated with alcoholic semi-normal potash solution until a constant violet color appears. It is better to use decinormal solution.

From the quantity of potash consumed and the quantity of fat obtained, the acid number requisite for the neutralization of 1 gramme of fat is calculated.

If the examination of a fat requires the determination of the content of acid, the *acid number* is first determined and then the *ester number*, the sum of both being the *actual Köttstorfer saponification number*. It indicates how many milligrammes of potassium hydroxide one gramme of fat requires for saponification. The determination of a saponification number is effected according to the same method as the ester number. The mean molecule weight—M—of the insoluble fatty acids in the oils, etc., is calculated from the saponification number—K—, or from the number of cubic centimeters—Cc—of semi-normal potash solution requisite for the neutralization of 1 gramme of fat or oil.

$$M = \frac{560000}{K}, \text{ or } \frac{2000}{Cc} = M.$$

ACID NUMBERS OF THE PURE FATTY ACIDS.

Fatty Acids.	Formula.	Molecular weight.	Sodium hydroxide NaOH.	Potassium hydroxide KOH.	100 parts by weight of fatty acid require		Acid number.
					Parts by weight NaOH.	Parts by weight KOH.	
Butyric	$C_4H_8O_2$	88	40	56	45.45	63.63	636.3
Capric	$C_{10}H_{20}O_2$	172			23.25	32.50	325.0
Caproic	$C_6H_{12}O_2$	116			34.48	48.28	482.8
Lauric	$C_{12}H_{24}O_2$	200			20.00	28.00	280.0
Linoleic	$C_{18}H_{28}O_2$	280			14.30	20.00	200.0
(Margaric)	$C_{17}H_{34}O_2$	270			14.82	20.74	207.4
Myristic	$C_{14}H_{28}O_2$	228			17.54	24.55	245.5
Oleic	$C_{18}H_{34}O_2$	282			14.19	19.86	198.6
Palmitic	$C_{16}H_{32}O_2$	256			15.62	21.87	218.7
Ricinoleic	$C_{18}H_{34}O_3$	298			13.76	18.80	188.0
Stearic	$C_{18}H_{36}O_2$	284			14.08	19.71	197.1

ACID NUMBERS OF THE FATTY ACIDS OF A FEW OILS, ETC.

Fatty Acids from	Acid Number.	Fatty Acids from	Acid Number.
Almond oil	204–205	Palm oil	206–207
Castor oil	187–188	Palm-kernel oil	265–266
Colza oil	181–182	Peanut oil	196–197
Cotton-seed oil	204–205	Poppy oil	204–205
Lard	215–217	Sesamé oil	197–198
Linseed oil	198–199	Sunflower-seed oil	201–202
Liver oil (medicinal)	202–204	Tallow (beef)	205–206
Nut oil	208–209	Tallow (sheep)	206–207
Olive oil	199–200		

Regarding the practical value of Köttstorfer's process, Alfred H. Allen, in a paper read before the Society of Public Analysts, June, 1886, says: "The practical value of Köttstorfer's process largely depends on the accumulation of evidence as to the limits of variation of neutralizing powers exhibited by different samples of oil of the same kind, and hence I have been at some trouble to collect data on the subject. These data are given in the following table, which contains results obtained by Köttstorfer (K.), F. W. and A. F. Stoddard (S.), L. Archbutt (L. A.), E. Valenta (V.), R. Moore (M.), Hübl (Hl.), Hehner (H.),

W. H. Deering (D.), A. H. Allen (A.), and many others. In many instances the figures are the average or extreme results yielded by the examination of a large number of samples. Still, a further experience will doubtless show that the limits stated in the table in many instances require modification.

"The table gives, in most cases, the number of samples on which the figures are based, together with the percentage of caustic potash required for saponification and the 'saponification equivalent' corresponding thereto. The last value is found by dividing the percentage of KHO required to saponify the oil into 5610. It presents the number of grammes of an oil which would be saponified by one liter of normal solution of any alkali. In the case of the glycerides, the saponification-equivalent is one-third of the molecular weight; but in the case of monatomic ethers, like those which essentially constitute sperm oil and beeswax, the saponification-equivalent is identical with the molecular weight:—

Nature of Oil.	Initial of Observer.	No. of samples.	Percentage of KHO for saponification.	Saponification equivalent.
A. OLEINS—				
Lard oil..........	S.	..	19.1 to 19.6	285 to 296
Olive oil	K., S., V.	30	19.1 to 19.6	
Olive oil	L. A.	40	18.93 to 19.26	
Almond oil (sweet)	V.	12	19.47 to 19.61	
Arachis oil	V., M.	2	19.13 to 19.66	
Tea oil...........	Davies.	1	19.55	
Sesamé oil........	V., M., A.	3	19.00 to 19.24	
Cotton-seed oil....	S., D., V., M., A.	8	19.10 to 19.66	
B. RAPE OIL CLASS—				
Colza and Rape oils	K., D., S.	8	17.08 to 17.90	313 to 330
Rape oil	L. A.	44	17.02 to 17.64	
Mustard-seed oil...	V., A.	2	17.4 to 17.5	
Cabbage-seed oil ..	Davies.	1	17.52	
C. VEGETABLE DRYING OILS—				
Linseed oil	S., D., M., L. A.	9	18.74 to 19.52	286 to 300
Poppy-seed oil	V., M.	2	19.28 to 19.46	
Hempseed oil. ...	V.	1	19.31	
Walnut oil........	V.	1	19.60	
Niger-seed oil.....	S.	2	18.9 to 19.1	

Nature of Oil.	Initial of Observer.	No. of samples.	Percentage of KHO for saponification.	Saponification equivalent.
D. MARINE OLEINE—				
Cod-liver oil	A., V.	2	18.51 to 21.32	250 to 303
Menhaden oil	A.	1	19.20	
Pilchard oil.......	S.	..	18.6 to 18.75	
Seal oil...........	S., D.	4	18.9 to 19.6	
Southern whale oil.	D.	1	19.31	
Northern whale oil.	S., A.	4	18.85 to 22.44	
Porpoise oil.......	A.	2	21.60 to 21.88	
E. BUTTER CLASS—				
Butter fat.........	K., V., M., A.	large	22.15 to 23.24	241 to 253
Cocoanut oil	V., M.	5	24.62 to 26.84	209 to 255
Palm-nut oil	V.	1	22.00 to 24.76	
F. STEARINS, ETC.—				
Lard	K., V., A.	7	19.20 to 19.65	277 to 294
Tallow...........	K., D.	9	19.32 to 19.80	
Dripping	K.	2	19.65 to 19.70	
Butterine.........	M., A.	large	19.35 to 19.65	
Goose fat.........	V.	1	19.26	
Bone fat..........	V., L., A.	2	19.09 to 19.71	
Palm oil..........	M., V.	3	19.63 to 20.25	
Cacao butter......	V.	1	19.98	
G. FLUID WAXES—				
Sperm oil.........	S., D., A.	10	12.34 to 14.74	380 to 454
Bottlenose oil.....	A., L. A., D.	5	12.30 to 13.40	419 to 456
H. SOLID WAXES—				
Spermaceti	H.	3	12.73 to 13.04	432 to 451
Beeswax	H., Hl., A.	large	9.2 to 9.7	..
Carnauba wax.....	Hl., V., H., L. A.	4	7.92 to 8.51	..
Chinese wax......	A.	1	6.5	..
I. UNCLASSED—				
Shark-liver oil	A.	8	14.00 to 19.76	284 to 400
Wool fat (suint) ..	V.	1	17.00	330
Lanolin	A.	1	9.83	570.9
Olive-kernel oil ...	V.	1	18.85	298
Castor oil	S., D., A., V.	6	17.60 to 18.15	309 to 319
Japanese wood oil..	Davies.	1	21.1	266
Japan wax........	H., Hl., V., A.	8	21.01 to 22.25	252 to 267
Myrtle wax	D., A.	2	20.57 to 21.17	265 to 273
Blown rape oil	L. A., A.	3	19.8 to 20.4	275 to 284
Colophony	H., A., D.	4	17.0 to 19.3	290 to 330

"On inspecting the results recorded in the foregoing table, it appears that the oils of Group A, consisting of olein with comparatively little stearin or palmitin, neutralize appreciably equal quantities of potash, and that whether they be of animal (like lard oil) or vegetable origin (*e. g.*, olive and almond oils). On the other hand, the oils of Group B, all of which are derived from cruciferous plants, neutralize sensibly less alkali than those of Group A, a fact which is explained by the presence of a considerable proportion of brassic acid, or other higher homologues of oleic acid, in rape oil and its allies. In the case of the drying oils, the saponification-equivalents are not characteristic, but they point to the probability of linoleic acid having a higher atomic weight than that commonly attributed to it. This suggestion receives support from a variety of facts which have passed under my notice, and I hope to refer to it more at length on a future occasion. The marine animal oils, Group D, do not yield very characteristic results, except in contrast with the figures of Group G, the oils of which are not glycerides, but consist essentially of ethers of monatomic alcohols. Porpoise oil is remarkable for the notable proportion of valerin contained in it, and hence for its comparatively high neutralizing power. Valeric acid is also the characteristic volatile fatty acid of the butter from porpoise milk. The glyceride of valeric acid also exists to a considerable extent in whale oil, blackfish oil, and dolphin oil. Chevreul obtained from the last-named oil as much as 20.9 per cent. of valeric acid.

"Of the solid fats, those of Group E resemble porpoise oil in containing glycerides of lower fatty acids, and hence possess lower saponification-equivalents than the oils of Group F, which consist essentially of variable mixtures of palmitin, stearin, and olein. Japan wax also contains a notable proportion of lower fatty acids. A sample examined by Hehner's butter method gave 88.4 per cent. of insoluble acids and 8.4 per cent. of soluble acids, calculated as $C_8H_{16}O_2$.

"The saponification-equivalent of rape-seed oil is very sensibly reduced by oxidation or 'blowing,' a fact which is probably due to the formation of lower fatty acids; but the changes produced in oils by oxidation much need further investigation by the aid of recent methods of analysis."

Values varying but little from those given in the preceding table have subsequently been collected and recorded by Schaedler and Benedikt, and are found in the appended table. The mean number, which is given beside the minimum and maximum numbers, is not always the arithmetical mean, but the number occurring most frequently as the mean with oils most thoroughly studied.

SAPONIFICATION NUMBERS OF SOME FATS, OILS, AND WAXES.

Names of Oils, Fats, etc.	Saponification number according to Schaedler.	Saponification number according to Benedikt.		
		Minimum.	Maximum.	Mean.
Almond oil, sweet	190–192	187.9	196.1	192
" bitter	—	194.5	196.6	195.5
Apricot kernel oil	192–193	—	—	192.9
Beeswax, yellow	95–100	97	107	—
Bone oil	190–191	—	—	—
Butter	225–230	—	—	227
Cacao butter	198–200	—	—	—
Carnauba wax	—	—	—	79
Castor oil	201–203	176	181.5	180
Charlock-seed oil	176–177	—	—	—
Cocoanut oil	255–260	—	—	255
Cod-liver oil, medicinal	175–185	171	213.2	185
" brown	180–200	—	—	—
Colza oil	177–178	175	179	177
Cotton-seed oil, refined	194–195	191	210.5	195
Galam butter	192–193	—	—	—
Hemp-seed oil	192–194	—	—	193.1
Japanese wax	222–223	—	—	
Lallemantia oil	184–185	—	—	185.0
Lard	195–196	—	—	—
Lard oil	—	191	196	193.5
Linseed oil	194–196	187.4	195.2	193
Maize oil	188–189	188.1	189.2	188.6
Menhaden oil	—	—	—	192
Mustard-seed oil	—	—	—	174
Neat's-foot oil	191–193	—	—	—
Niger oil	189–191	189	191	190
Nut oil (walnut)	196–197	—	—	196.0
Olive oil, salad	191–193	185.2	196	193
" inferior	186–188			
Olive kernel oil	188–189	—	—	188.5
Palm oil	201–202	—	—	—
Palm kernel oil	246–248	—	—	257.6
Peanut oil	194–196	190.1	197	193.5
Pilchard oil	—	186	187.5	186.7
Piney (Malabar) tallow	191–192	—	—	—
Poonseed oil	199–200	—	—	—
Poppy oil	193–194	192.8	194.6	193.7

SAPONIFICATION NUMBERS OF SOME FATS, OILS AND WAXES.

Names of Oils, Fats, etc.	Saponification number according to Schaedler.	Saponification number according to Benedikt.		
		Minimum.	Maximum.	Mean.
Porpoise oil, from jaw	—	—	—	143.9
" fluid portion	—	253.7	272.3	263
Pumpkin-seed oil	189–190	—	—	189.5
Purgir nut oil	230–231	—	—	230.5
Rape seed	177–179	—	—	177
Seal oil	180–195	191	196	193.5
Sesamé oil	192–193	187.6	192.2	190
Shark liver oil	—	—	—	84.5
Spermaceti	108	—	—	108.1
Spermaceti oil	134	130	134.4	132.2
Sunflower-seed oil	193–194	—	—	193
Tallow (beef)	193–195	—	—	—
Tallow (sheep)	192–195	—	—	—
Ungnadia oil	190–192	—	—	—
Whale oil	190–191	190	191	190.5
Whale oil, bottlenose	—	—	—	197.3
" fluid portion	—	—	—	290.0
Wild radish-seed oil	174–175	—	—	174
Wool fat	169–170	—	—	—

Based upon the results of his experiments, Allen divides the oils into three groups:

1. *Saponification number, 189–196.* Lard oil, olive oil, niger oil, cotton seed oil, linseed oil, whale oil, seal oil.

2. *Saponification number, 175–189.* Colza oil, rape oil, liver oil, pilchard oil, castor oil.

3. *Saponification number below 175.* Spermaceti oil, shark oil.

Valenta also distinguishes three groups of oils:

1. *Mean saponification number, 193.0.* Apricot kernel oil, almond oil, bitter almond oil, peanut oil, cotton-seed oil, olive oil and sesamé oil.

2. *Mean saponification number, 188.1.* Pumpkin-seed oil, olive kernel oil.

3. *Mean saponification number, 177.1.* Colza oil, rape oil, wild radish-seed oil, castor oil.

The saponification number may therefore be used for distinguishing oils of cruciferous plants (colza, rape, wild radish-seed oils) from other oils, especially those of the first group. From castor oil, which stands in the same group, they are distinguished by dissolving with difficulty in alcohol. The method may further be utilized for the recognition of fluid varieties of wax which have remarkably low saponification numbers. The fluid portions of porpoise and dolphin oils, which are used as fine lubricants, are distinguished by very high saponification numbers.

The low saponification number of the oils of Valenta's third group is due to the large content in these oils of acids of high molecular weight, for instance, brassic acid in colza oil and ricinoleic acid in castor oil.

In speaking of the determination of glycerin, p. 124, it has been mentioned that from the results of the saponification of of oils, fats, etc., which besides the triglycerides contain no esters of the monatomic alcohols, such as spermaceti oil, shark liver oil, etc., the glycerin can be calculated, $C_3H_5(XO)_3$ fat + 3KOH (potassium hydroxide) = 3XOK (soap) + $C_3H_8O_3$ (glycerin). The saponification number and the acid number are determined according to the Köttstorfer method, and the acid number (hence the milligrammes potassium hydroxide calculated for 1 gramme fat) is deducted from the saponification number, the remainder of the milligrammes of potassium hydroxide corresponding in the proportion of 168 : 92 to the glycerin. 100 milligrammes of potassium hydroxide = 0.0547 milligrammes glycerin.

There are required for the saponification of 100 parts

Fatty Acids and Glycerides.	Sodium hydroxide NaOH Parts	Potassium hydroxide KOH Parts
Stearic acid	735.0	507.1
Palmitic acid	671.0	457.1
Oleic acid	741.5	503.5
Stearin	705.0	535.7
Palmitin	640.0	479.7
Olein	700.0	530.9

After saponification, fats and oils give the following yields:

YIELD OF FATTY ACIDS AND GLYCERIN FROM THE TRIGLYCERIDES.

Triglyceride of	Molecular weight of the tri-glycerides.	Molecular weight of the fatty acids.	Fatty acids per cent.	Glycerin per cent.	Total.
Butyric acid	302	88	87.41	30.64	118.05
Capric acid	594	172	93.14	15.48	108.62
Caproic acid	386	116	90.16	23.83	113.99
Lauric acid	638	200	94.04	14.42	108.46
Myristic acid	722	228	94.47	12.74	107.21
Margaric acid	848	270	95.52	10.85	106.37
Oleic acid	884	282	95.70	10.40	106.10
Palmitic acid	806	256	95.28	11.41	106.69
Stearic acid	890	284	95.73	10.33	106.06

2. *Determination of the Fatty Acids Insoluble in Water.—Hehner's Number.*

The fatty acids insoluble in water commence in the acetic acid series with lauric acid, $C_{12}H_{24}O_2$. Butyric, caproic and capric acids, as well as the fatty acids with odd carbon-atoms—valerianic, isovalerianic, etc., acids—occurring in rancid and putrid fats and train oils, are soluble in water. To the insoluble acids belong further, oleic acid and ricinoleic acid and their homologues.

For their determination 5 to 10 grammes of pure filtered fat, etc., are heated together with 2 to 4 grammes of dry caustic soda or caustic potash, 50 to 100 cubic centimeters of water, and 15 to 30 cubic centimeters of alcohol. The alcohol promotes saponification and prevents foaming. When saponification is complete, heating is continued until the alcohol is expelled. The soap paste is then diluted with a small quantity of water and decomposed with hydrochloric acid. The mixture is allowed to stand quietly, and when cold the fatty acids are lifted off, washed with luke-warm water, dried first with filtering paper, next by careful heating in a porcelain dish, and later on weighed. With oils it is necessary, and generally advantageous also with soft fats, to add, corresponding to the quantity of fat used, 2 or 3 grammes of paraffin fusing at about 149° F., and deduct the paraffin later on.

The paraffin added does not prevent the alkalimetric determination of the fatty acids or of the saponification number, if such determinations have to be made. The acid number is determined according to Köttstorfer's method.

CONTENT OF INSOLUBLE FATTY ACIDS IN SOME FATS, ETC.

Names of Oils, etc.	Insoluble fatty acids, per cent.	Names of Oils, etc.	Insoluble fatty acids, per cent.
Almond oil	94.02	Margarin oil	95.60
Butter fat	87–88	Olive oil	94.03
Cacao butter	94.73	Palm oil	86.20
Charlock-seed oil	95.20	Poppy oil	95.97
Cod-liver oil	93.87	Sesamé oil	95.82
Colza oil	96.00	Suet (beef tallow)	94.20
Cotton-seed oil	95.30	Tallow (sheep)	94.50
Goose grease	95.47	Ungnadia oil	94.22
Illipé butter	95.64	Veal fat	94.54
Lard	95.50		

Hehner's number is equal to the percentage of solid fatty acids in a fat, and is therefore calculated to 100 parts fat, etc.

It is frequently necessary to determine the fusing and solidifying points of the fat, which is done according to the methods previously given. Some results will be found in the appended table:

FUSING AND SOLIDIFYING POINTS OF FATTY ACIDS FROM VARIOUS OILS, ETC.

Names of Oils, etc.	Fatty acids therefrom.		Names of Oils, etc.	Fatty acids therefrom.	
	Fusing point °F.	Solidifying point °F.		Fusing point °F.	Solidifying point °F.
Almond oil	57	41	Olive oil	72.5–73.5	61–62.5
Apricot-kernel oil	40	32	Palm oil	167–169	107.5–109
Bone oil	82.5	79	Peanut oil	79–80.5	77
Butter fat	98.5–100.5	91.5–93	Piney tallow	134	130
Cacao butter	121	116–116.5	Poonseed oil	98	88
Castor oil	55.5	37.5	Poppy oil	69	62
Charlock-seed oil	65.5–66	52–53.5	Pumpkin-seed oil	80.5–82.5	75
Chinese tallow	134.5	125.5	Rape oil	70	55.5
Cocoanut oil	75–77	68–69	Rubsen oil	64.5	55.5
Colza oil	68–70	57–58	Sesamé oil	77–79	71–72
Cotton-seed oil	93–95	87	Spermaceti oil	56	—
Galam butter	96	86	Suet (beef tallow)	114	109.5
Hemp-seed oil	66	59	Sunflower-seed oil	73.5	62.5
Lallemantia oil	52–53.5	—	Tallow (sheep)	120	115
Lard	100.5–102	95	Ungnadia oil	66	50
Linseed oil	62.5	56	Walnut oil	68	61
Margarin	107.5	103	Wool grease	107	104
Nutmeg butter	108.5	104			

3. *Determination of the Volatile Fatty Acids—Reichert's Number.*

Reichert's number originally indicated the number of cubic centimeters of decinormal alkali required for the neutralization of the volatile fatty acids obtained from 2.5 grammes of fat. At present Meissl's modification of Reichert's process is almost exclusively used: 5 grammes of fat are brought into a flask and saponified with 2 grammes of dry caustic potash and 50 cubic centimeters of spirit of wine of 0.872 specific gravity. After driving off the alcohol the soap is dissolved in 100 cubic centimeters of water, and mixed with 40 cubic centimeters dilute—about 10 per cent.—sulphuric acid of specific gravity 1.060. For distillation of the mass the flask is connected with a Liebig receiver, and 110 cubic centfmeters distilled off.

100 cubic centimeters of the distillate are then titrated with decinormal potash, using phenolphthalein as indicator, and the number of cubic centimeters of decinormal potash consumed

increased $\frac{1}{10}$ to correspond to the total quantity of distillate. To facilitate the driving off of the fatty acids the introduction of steam into the decomposed soap-paste is of advantage. Any solid fatty acids carried along are filtered off.

The *Reichert–Meissl number* is the number of cubic centimeters of decinormal potash, which have been consumed for the saturation of the volatile fatty acids soluble in water obtained from 5 grammes of fat.

The Reichert–Meissl number generally refers only to butter fat, which should not consume less than 27 to 29 cubic centimeters of the decinormal potash; pure butter fat, according to the above process, requiring 27 to 31 cubic centimeters.

For the other fats and oils, with the exception of cocoanut oil and palm-kernel oil, this number is of less importance, the differences between the separate triglycerides being too slight. The rancidity of the oils exerts no special influence upon the alkalimetric results.

The appended table gives the content of volatile fatty acids in some fats:

Names of Oils.	Cubic centimeters of decinormal potash.	Names of Oils.	Cubic centimeters of decinormal potash.
Almond oil	0.55	Peanut oil	0.4
Castor oil	4.0	Poppy oil	0.60
Cocoanut oil	7.3	Rape oil crude	0.90
Cod-liver oil	0.40	Rape oil refined	0.58
Cotton-seed oil	0.95	Seal oil	2.6
Lard	1.10	Sesamé oil	1.2
Linseed oil	0.95	Suet (beef tallow)	1.0
Olive oil	1.5	Sunflower seed oil	0.5
Palm oil	0.5	Tallow (sheep)	1.2
Palm kernel oil	3.4	Walnut oil	0.92

Like with all new methods of technical analysis, a large number of modifications of Reichert's excellent test have been proposed, most of which are immaterial and offer no advantage.

Wollny's assertion that the process executed according to the Reichert-Meissl method gives throughout faulty results, has been refuted by Raumer and by Sendtner. However, since many results of tests of fat according to Wollny have passed into literature, his method may, for the sake of completeness, be given.

Determination of Reichert's number according to Wollny.[*] 5 grammes of clear filtered fat are brought into a flask of 300 cubic centimeters capacity (round shape, length of neck, 7 to 8 centimeters, width of neck, 2 centimeters), and 2 cubic centimeters of 50 per cent. soda lye, and 10 cubic centimeters of 96 per cent. alcohol added. The whole is then heated on a boiling water-bath with a reflux condenser attached, for ¼ hour, and gently agitated at intervals. The alcohol is then distilled off from the closed flask, whereby the latter must lie at least ½ half hour in the boiling water-bath. By means of a pipette 100 cubic centimeters of distilled water are then brought into the flask, the latter, to insure against evolution of carbonic acid, remaining ¼ hour in the water-bath, so that the soap is completely dissolved. The clear solution is then cooled off to 122° or 140° F. —but not below—by allowing water to run over the flask, and immediately mixed with 40 cubic centimeters of sulphuric acid,[†] and two pieces of pumice stone the size of a pea. The flask is then immediately connected with the cooler by means of a piece of rubber tubing, which should not be too narrow. For the cooler serves a glass tube 0.7 centimeter in diameter which, 1 centimeter above the cork, is blown into a bulb 2 to 2.5 centimeters in diameter, and immediately above it is bent upward in an obtuse angle; it then runs in this direction about 5 centimeters, when it is again bent in an obtuse angle obliquely downward. The mixture in the flask is heated, without boiling, by a small flame until the insoluble fatty acids are fused to a clear transparent mass, when exactly 110 cubic centimeters are distilled off into a measuring flask inside of half an hour. After mixing thoroughly by shaking, 100 cubic centimeters are filtered from the measuring flask into another flask, then emptied into a beaker and titrated with decinormal barium solution, using 1 cubic centimeter phenolphthalein solution (0.5 gramme phenolphthalein to 1 liter 50 per cent. alcohol) as indicator. When a red color has appeared the contents of the beaker are poured back into the flask; the dissolved fluid is then returned to the beaker and titrated until a just perceptible red coloration appears. From the number of cubic centimeters consumed, multiplied by 1.1, the number has to be deducted, which is obtained by a blind experiment (without fat) executed in the same manner; this number should not be more than 0.33.

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[*] Zeitschrft f. Analyt. Chemie, 21, 394.

[†] 25 cubic centimeters of sulphuric acid to 1 liter of water, of which 30 to 35 cubic centimeters are required for the neutralization of two cubic centimeters of the soda lye used.

4. *Determination of the Fatty Acids of the Non-saturated Hydrocarbons—Oleic Acid and Linoleic Acid Series—Iodine Number.*

The *iodine absorption process* of Baron Hübl is based upon the fact that all fats contain acids of various series: *Homologues of acetic acid* $C_nH_{2n}O_2$—lauric, myristic, palmitic, stearic acids, etc.; *homologues of acrylic acid*—$C_nH_{2n-2}O_2$—erucic, hypogæic, oleic acids, etc.; and *homologues of tetrolic acid*—$C_nH_{2n-4}O_2$—linoleic acid, etc.

In one and the same fat the quantities of these acids seem to be within definite limits, while in different fats they appear to vary. The above mentioned three series of acids show a very characteristic difference in their behavior towards halogens—chlorine, bromine iodine—the acids of the saturated hydrocarbons, hence those belonging to the acetic acid series, being under ordinary conditions indifferent towards these bodies, while the acids of the non-saturated hydrocarbons absorb halogens, *viz.*, those of the acrylic acid series and ricinoleic acid 2 atoms, and those of the tetrolic acid series 4 atoms. Hence, according to the varying composition of the fats, the quantity of the apparently absorbed haloid must vary, especially as there is a difference in the molecular quantity of the acids.

Of the halogens, iodine has been found most suitable. Experiments to determine the quantity of *bromine* which a fat is capable of absorbing were first made by Cailletet (1857), next by Allen,* and further by Mills in connection with Snodgrass† and Akill.‡ Levallois,§ Halphen ‖ and Schlagdenhaufen and Braun ¶ have also experimented with this method. However, in practice the use of iodine, especially in the form proposed by Hübl, has been found preferable.

At the ordinary temperature the action of iodine upon fats is very sluggish, and at an increased temperature not uniform; but in the presence of mercuric chloride an alcoholic iodine solution acts readily upon the non-saturated fatty acids, absorption-products of chloride of iodine being formed, while the saturated fatty acids remain unchanged. Most fats, as well as the fatty acids, being soluble with difficulty in alcohol, solubility is promoted by an addition of chloroform.

Hübl's iodine number indicates the quantity of iodine which fixes 100 grammes of fatty acid or fat.

ABSORPTION OF IODINE BY THE FATTY ACIDS OF THE NON-SATURATED HYDROCARBONS.

Names of fatty acids.	Formula.	Absorption of iodine atoms.	100 grammes of acid absorb iodine—Iodine number.
Erucic acid	$C_{22}H_{12}O_2$	2	75.15 grammes
Hypogæic acid.......	$C_{16}H_{30}O_2$	2	100.00 "
Linoleic acid	$C_{16}H_{28}O_2$	4	201.59 "
Linolic acid.	$C_{18}H_{32}O_2$	4	181.43 "
Linolinic acid.............	$C_{18}H_{30}O_2$	6	274.10 "
Oleic acid	$C_{18}H_{34}O_2$	2	90.07 "
Ricinoleic acid.......	$C_{18}H_{34}O_3$	2	85.24 "

For the determination of the *absorption of iodine* the following solutions are required:

1., *Iodine solution.* This solution is prepared by dissolving, on the one hand, 25 grammes of iodine in 500 cubic centimeters of 98 per cent. alcohol free from fusel oil (specific gravity 0.800), and, on the other, 30 grammes of mercuric chloride in 500 cubic centimeters of alcohol, filtering the latter solution, if necessary, and mixing the two solutions. Since the compound solution at first loses strength, it should be allowed to stand at least 15 hours before use.

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* Jour. of the Soc. of Chem. Industry, 1884, 65.

† Ibid, 1883.

‡ Ibid, 1884.

§ Jour. Pharm. Chim., 1887, i. 333.

‖ Jour. Pharm. Chim., 1889, 20, 247.

¶ Mon. Scient., 1891, 591.

2. *Sodium hyposulphite solution.* Dissolve 24.8 grammes of pure well-crystallized sodium hyposulphite in a liter of distilled water. The solution is durable if kept in the dark, or in a dark bottle. The sodium hyposulphite solution is standardized with chemically pure, freshly sublimated iodine. Weigh off exactly 0.20 gramme iodine and dissolve it in 1 gramme potassium iodide and 10 grammes of water in a beaker. When solution is complete add, by means of a burette, of the sodium hyposulphite solution to be standardized until a slight yellow coloration appears. Then add some starch solution whereby the color is changed to blue, and continue titration carefully until, by the addition of one drop, the blue color disappears. This hyposulphite solution serves for the determination of the value of Hübl's iodine solution, 10 cubic centimeters of which approximately consume 20 cubic centimeters sodium hyposulphite solution.

3. *Chloroform.* This must be tested, before use, as to its purity, by mixing 10 cubic centimeters of it with 10 cubic centimeters of Hübl's iodine solution and determining after 2 or 3 hours the quantity of iodine in this mixture, as well as in the 10 cubic centimeters of iodine solution used. If the two numbers agree the result is the same.

4. *Potassium iodide solution.* Dissolve 1 part potassium iodide in 10 parts water. The potassium iodide should be free from potassium iodate.

5. *Starch solution.* Starch powder is gradually stirred together with 100 times its weight of distilled water and heated to boiling, stirring constantly. By adding to the cold solution a few drops of alcoholic salicylic acid solution, it will keep for a long time.

The operation of the iodine absorption process is as follows: Weigh out into a light thin-walled flask of 200 cubic centimeters capacity and provided with a glass stopper, of drying oils 0.2 to 0.3 gramme, of non-drying oils 0.3 to 0.4 gramme, and of fats 0.8 to 1 gramme. Fats are first carefully melted in a small glass. The respective fat is dissolved in 10 cubic centimeters chloroform, and 20 cubic centimeters of iodine solution added. If, after agitation, the fluid is not clear, add some more chloroform; and if in a short time it becomes almost discolored, add 10 cubic centimeters more of iodine solution. In 1½ to 2 hours reaction is complete, and the quantity of iodine added in excess is then determined by mixing the fluid with 10 to 15 cubic centimeters of potassium iodide solution, agitating, diluting with 150 cubic centimeters of water, back-titrating carefully with sodium hyposulphite until a slight yellowish coloration appears, then adding some starch solution, and finishing titration (with the flask closed), agitating frequently. The difference between the iodine solution used and back-titrated gives, with regard to the strength of the hyposulphite solution, the quantity of iodine fixed by the fat. The quantity of iodine found, Hübl gives in per cent. of the fat, and calls this number the *iodine number*.

The age of the fat is without perceptible influence upon the iodine number, as long as its composition has not suffered far-reaching changes, for instance, by long-continued action of the air, of light, etc.

This method may be made still more useful by determining the iodine number not for the fats themselves, but for the fatty acids separated from them. In this case the determination of the fusing points of the fatty acids may be combined with the test.

Hübl's iodine solution rapidly loses strength, this change being due to a decomposition of ketone and aceton bodies contained in alcohol. It is therefore best to keep the two solutions—alcoholic iodine solution and mercuric chloride solution—separate, and only mix them 6 to 12 hours before use.

The appended table contains the iodine numbers for fluid fats determined by Hübl[*] and by Moore: [†]

Character of the Oils.	Names of Oils.	Iodine Number according to Hübl. (Mean)	Iodine Number according to Moore.
I. Drying	Linseed oil	158	155.2
II. Drying	Hemp-seed oil	143	—
	Nut oil	143	—
	Poppy oil	136	134.0
	Pumpkin-seed oil	121	—
III. Undetermined (Moderately Drying)	Sesamé oil	106	102.7
	Cotton-seed oil	106	108.7
	Peanut oil	103	87.4
	Rape-seed oil	100	103.6
IV. Non-drying	Apricot kernel oil	[100	—
	Almond oil (sweet)	98.4	98.1
	Mustard oil	—	96.0
	Castor oil	84.4	—
	Olive oil	82.8	83.0
	Olive kernel oil	81.8	—
V.	Bone oil	68.0	—

Since the publication of Hübl's method in testing oils, the iodine number is first determined, so that numerous statements are found in literature which all prove the constancy of the iodine number of each variety of oil within narrow limits. Thus Dieterich alone has examined 200 olive oils, and always found their iodine number between 81.0 and 84.5. The drying oils only, especially linseed oil, showed greater differences, because, on the one hand, the determinations had been made with an insufficient excess of iodine, and, on the other, the iodine numbers of older oils are lower.

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[*] Dingler's Jour., 253, 281.

[†] Am. Jour., 6, No. 6.

IODINE NUMBERS OF SOME OILS, ETC., AND OF THE FATTY ACIDS SEPARATED THEREFROM.

Names of Oils, etc.	Iodine numbers		Names of Oils, etc.	Iodine numbers	
	Of the oils.	Of the fatty acids.		Of the oils.	Of the fatty acids.
Almond	82–83	87–90	Palm	51.5	—
Apricot kernel	100–102	—	Palm kernel	13.5–14	12
Bone	60–68	56–57	Peanut	94–96	96–97
Butter	28–32	—	Poonseed	63	—
Cacao butter	34	—	Poppy	134–135	—
Castor oil	93–94	87–88	Pumpkin seed	121	—
Charlock	96–97	—	Purgir-nut	127	—
Cocoanut	9–9.5	8.5–9.0	Rape-seed	98–100	—
Cod-liver medicinal.	128–130	—	Seal	125–130	—
brown	135–140	—	Sesamé	103–105	110–111
Colza	100–101	97–99	Spermaceti	108	—
Cotton-seed	106–107	112–115	Spermaceti oil	88	—
Hemp	143–144	122–124	Sunflower	129	133–134
Japanese wax	4.2	—	Suet (beef tallow)	38–40	26–30
Lallemantia	162	167	Tallow (sheep)	43–44	—
Lard	59–60	—	Ungnadia	81.5–82	86–87
Linseed	177–178	155	Walnut	142–143	—
Maize	119.5	125	Wild radish-seed	105	—
Olive (salad)	82–83	87–88	Wool grease	36	—
Olive kernel	82	—			

The following tables represent the collected results published during the last few years by Hübl, Moore, Dieterich, Wilson, Erban, Herz, Spüller, Horn, Richter, Kremel, Beringer, Benedikt, and others, and recorded by Benedikt.*

* Analyse der Fette und Wachsarten, 2te Auflage, 1892.

IODINE NUMBERS OF LIQUID FATS.

Names of Fats.	Iodine Number.		
	Minimum.	Maximum.	Mean.
Linseed oil, fresh	170	181	175
Linseed oil, commercial	148	181	170
Lallemantia oil	—	—	162
Hempseed oil	142	158	150
Nut oil	143	152	146
Poppy oil	134	142	138
Sunflower-seed oil	122	133	128
Purgir-nut oil	—	—	127
Pumpkin-seed oil	—	—	121
Maize oil	—	—	120
Cod-liver oil	126	153	140
Seal oil	127	128	127
Merlin oil (coal-fish oil)	123	137	130
Japanese cod-liver oil	—	—	120
Cotton-seed oil	102	111	108
Sesamé oil	103	112	108
Wild radish-seed oil	—	—	105
Rape-seed oil	99	105	101
Apricot kernel oil	99	102	100
Bottlenose oil	—	—	99.5
Almond oil	96	102	98
Peanut oil	87.3	103	96
Mustard oil	—	—	96
Castor oil	83	85	84.5
Olive oil	81	84.5	82.8
Olive kernel oil	—	—	81.8
Ungnadia oil	—	—	81.7
Porpoise oil	—	—	76.8
Neat's foot oil	—	—	70.3
Bone oil	66	70	68
Porpoise oil, fluid portion	30.9	49.6	40.2
Bottlenose oil, fluid portion	—	—	32.8

Iodine Numbers of Solid Fats.

Names of Fats.	Iodine number.		
	Minimum.	Maximum.	Mean.
Cotton-seed stearin	—	—	89.6
Goose grease	—	—	71.5
Lard	56	63	59
Macassar oil	—	—	53
Bone grease, commercial	46.3	55.5	52
Palm oil	50.3	53.9	51
Oleomargarine	—	—	50
Laurel butter	—	—	49
Suet (ox tallow)	40	44	42
Tallow (sheep)	32.7	46.2	42
Wool fat	—	—	36
Cacao butter	34	37.7	36
Nutmeg butter	—	—	31
Butter fat	19.5	38.0	30
Palm-kernel oil	10.3	17.5	14
Ocuba wax	—	—	9.5
Cocoanut oil	9.4	9	9
Japanese wax	—	—	4.2

Bromine process. Reference to this process has been made on p. 202, and although, as stated there, the use of iodine has been found preferable in practice, for the sake of completeness, a few methods of making the test will here be given.

Mills dissolves 0.1 gramme of the dry fat in 50 cubic centimeters of carbon tetrachloride, and adds titrated solution of bromine in carbon tetrachloride. After 15 minutes, the excess of bromine is back-titrated with a solution of β-naphthol in carbon tetrachloride, whereby monobromnaphthol is formed.

Halphen back-titrates the excess of bromine with soda solution prepared by diluting 20 cubic centimeters of soda lye to 1 liter and adding 2 grammes eosin. The solution is standardized by bringing into a flask of 125 cubic centimeters capacity 20 cubic centimeters of carbon disulphide and 10 cubic centimeters of bromine solution of a known standard, and gradually adding soda lye, shaking after each addition. The fluid is at first brownish, then almost colorless, and finally salmon color. The value of the soda lye is calculated to bromine. The bromine solution has to be standardized anew before each experiment.

For the determination of the bromine absorbing capacity, dissolve in a flask of 250 cubic centimeters capacity 1 gramme of the fatty acids in 20 cubic centimeters of carbon disulphide, and enough bromine solution that there is an excess of at least 0.5 gramme. Shake repeatedly, then allow to stand 15 hours, and titrate with soda lye.

Schlagdenhaufen and Brown dissolve about 2.5 grammes of oil in 50 cubic centimeters of chloroform, take 10 cubic centimeters of the solution and mix them, in portions, with a solution of about 1 gramme of bromine in 100 cubic centimeters of chloroform until the excess of bromine does no longer disappear on shaking, and the fluid shows a yellow color. It is then mixed with 10 cubic centimeters of dilute potassium iodide solution and with starch paste, and titrated with hyposulphite.

5. *Determination of the Oxy-fatty Acids—Acetyl number.*

The acetyl number allows of the quantitative determination of the hydroxyl content of a substance, and therefore furnishes a measure for the content of oxy-fatty acids or fatty alcohols in a fat, mixture of fats, or constituent of a fat.

According to Benedikt and Ulzer,* the determination of the acetyl number of fatty acids is carried out as follows: The oils, etc., to be examined are saponified in the previously described manner, and the resulting soap decomposed with a mineral acid to separate the fatty acids. Of the insoluble fatty acids of the oil to be examined 20 to 50 grammes are brought into a small flask with inverted condenser attached, and are boiled for two hours with an equal volume of acetic anhydride. The mixture is then emptied into a tall beaker of 1 liter capacity, and after adding 500 to 600 cubic centimeters of water, boiled at least for ½ hour. To avoid bumping, a slow current of carbonic acid is introduced through a capillary tube entering near the bottom of the beaker. The water is then siphoned off, and the boiling repeated in the same manner until litmus paper is no longer reddened by the water. The water is then entirely siphoned off, the acetylated acids filtered in an air-bath through a dry filter, and the *acetyl-acid* number and *acetyl number* of the fatty acids are then determined. This is effected in the same manner as the determination of the acid and ester numbers of a fat; aqueous instead of alcoholic potash solution may, however, be used. Dissolve 3 to 5 grammes of the acetylated fatty acid in spirits of wine free from acid and fusel oil, add phenolphthalein, and titrate with semi-normal potash solution until a red coloration appears. Then add an excess of the same semi-normal potash solution, heat on a water-bath to gentle boiling, and back-titrate with hydrochloric acid.

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* Monatshefte für Chemie., viii. 40.

The sum total of the acetyl-acid number and of the acetyl number is called "*acetyl saponification number.*" Hence for the determination of the acetyl number, the saponification number and acid uumber of the acetylated fats may be determined and the acetyl number found from the difference. The acetyl number is = 0, if the sample contains no oxy-fatty acids.

Example: 3.379 acetylated fatty acids from castor oil required for saturation 17.2 cubic centimeters decinormal potash solution or 17.2 × 0.02805 grammes = 0.4825 gramme of potassium hydrate, from which results the acetyl-acid number 482.5 : 3.379 = 142.5.

To the neutralized sample were added 32.8 cubic centimeters more of potash solution, or a total of 50 cubic centimeters. After boiling, the fluid was back-titrated with 14.3 cubic centimeters of semi-normal hydrochloric acid. Consequently there remain for the saturation of the acetic acid split off 32.8 — 14.3 = 18.5 cubic centimeters of semi-normal potash solution or 18.5 x 0.02805 = 0.5189 potassium hydrate, from which results the *acetyl number* 518.9 : 3.379 = 153.5.

The acetyl number allows especially the recognition of castor oil and "oxidized oils" in mixtures of oil. Benedikt and

Ulzer[*] have tested the following oils as to their acetyl number:

ACETYL NUMBERS OF SOME OILS.

Fatty Acids from	Not acetylated.	Acetylated.		
	Acid number.	Acetyl acid number.	Acetyl saponification number.	Acetyl number.
Almond oil	201.6	196.5	202.3	5.8
Castor oil	177.4	142.8	296.2	153.4
Cotton-seed oil	199.8	195.7	213.3	16.6
Croton oil	201.0	195.7	204.2	8.5
Hemp-seed oil	199.4	196.8	204.3	7.5
Linseed oil	201.3	196.6	205.1	8.5
Nut oil	204.8	198.0	205.6	7.6
Olive oil	197.1	197.3	202.0	4.7
Peach-kernel oil	202.5	196.0	202.4	6.4
Peanut oil	198.8	193.3	196.7	3.4
Poppy oil	200.6	194.1	207.2	13.1
Rape-seed oil	182.5	178.5	184.8	6.3
Sesamé oil	200.4	192.0	203.5	11.5
"Soluble castor oil"	—	184.5	246.7	62.2

6. *Tests for Impurities and Adulterations.*

A. *General Methods.*

The general methods embrace the determination of the *content of water, of additions (particles of dirt), of mucus, of the content of fatty and mineral acids, of mineral and rosin oils in fat oils, of fat oils in mineral oils and soaps in oils; further, the determination of the drying and non-drying portions of an oil.*

1. *Determination of the Content of Water and Additions—Particles of Dirt, etc.*

In speaking of the solubility of vegetable oils, it has been mentioned that, even when perfectly clear, they may contain about 0.5 per cent. water. Mineral oils contain up to 1 per cent. In oils which are to serve as lubricants for fine machines, clocks, watches, etc., even such content is injurious. By simply heating a weighed quantity of oil in an open beaker, traces of water remain behind, and the determination has therefore to be made in a calcium chloride tube, Fig. 36. Weigh 10 grammes of oil in the tube and note the total weight of both. Then suspend the tube in a steam or air bath, heat to 122° or 140° F., and slowly conduct through it for ½ hour perfectly dry carbonic acid gas. After cooling, the tube is again weighed; the difference in weight gives the content of water.

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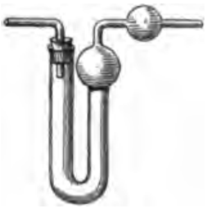
[*] Zeitschrift für Chemie, 1887, 8, 41.

FIG. 36.



Considerable quantities of water may be, and are frequently, added to fats without changing their appearance. For the determination of water in such a case, heat 50 grammes of the fat in a graduated cylinder in an air bath a few degrees above the fusing point. Leave the fat in this state for about 4 to 6 hours, during which time the water separates together with any salts, such as borax, potash, which may have been added to augment the content of water. The cubic centimeters of water are then simply read off. When the fat contains but a small quantity of water it is tested in the calcium chloride tube previously described. An addition of *potash* is recognized by the alkaline reaction with litmus paper, after shaking the fat with water. For the determination of *borax* the water poured off from the fat is evaporated to dryness, the residue mixed with a few drops of sulphuric acid, later on with spirits of wine and, after the latter has acted for some time, ignited. In the presence of borax the flame burns with a green edge. *Alum* is also added for the purpose of augmenting the quantity of water; it shows an acid reaction with litmus. For its detection the fat is shaken with water containing hydrochloric acid; the extract gives with ammonia a jelly-like precipitate.

By the above mentioned method of determining the water by fusing, particles of dirt or intentional adulterations of the fats are also separated, the latter consisting chiefly of amylaceous substances, chalk, etc. The fat having been poured off from the adulterations, the latter are washed with petroleum-ether, benzine, etc., or when water is also present, with water, and examined with the microscope or tested with iodine solution which colors *starch* blue. Effervescence when pouring dilute hydrochloric acid over another portion of the adulterations indicates the presence of *chalk*. For quantitative determination the portion insoluble in petroleum-ether or water is collected upon a weighed filter, dried at 212° F., and again weighed.

Particles of dirt—sand and dust—are readily recognized in the residue.

Pouring off of the water, etc., is facilitated by reheating the graduated tube containing the fat, then closing the tube with a cork and inverting it.

If a quantity of fat in a beaker is at first dried at 230° F., and stirred at intervals, then without stirring at 248° F. for two hours, and an aliquot part filtered through a weighed filter, *glycerin* remains behind in the fibres of the filter. The filter is washed with hot benzol, then dried at about 194° F., and later on weighed. If the filter remains moist, it is freed from glycerin by washing with alcohol, again dried and weighed. The difference gives nearly the true content of glycerin.

2. *Detection of Mucus.*

Mucus is detected by frequent vigorous shaking of equal volumes of oil and water. With oil free from mucus the water settles clear, while in the presence of particles of mucus it shows a whitish turbidity which cannot be removed even by frequent filtering. After long standing a white flaky layer is formed between the oil and water. Frequently the particles of mucus also deposit on the bottom.

3. *Determination of the Content of Acid—Acid Degrees.*

The content of acid in an oil, etc., may be due, 1, to the free fatty acids peculiar to the fat or oil; 2, to unripe seeds used in expressing the oil, the content of acid in the seed being like the content of fat dependent on climatic conditions, etc.; 3, to rancidity; 4, to careless washing after refining the oil with sulphuric acid, etc.

According to an old method, *free fatty* acids color oils green when left in content with *copper scales*, a green zone being formed above the copper. In the presence of fatty acids, oils are colored red by *rosaniline*. The latter is best dissolved in alcohol, a few drops of the solution added to the oil, and the latter somewhat heated.

Oils free from acid when shaken with solution of soda free from caustic soda, or solution of borax, separate on standing into two clear layers. In the presence of more or less acid an emulsion is accordingly formed and the layers remain turbid.

For the quantitative determination of free fatty acids, 10 grammes of oil are treated according to Köttstorfer's saponification method, p. 185, and titrated with semi-normal potash. *The fatty acids are calculated to oleic acid.*

The following table gives the content of free fatty acids in various fats and oils.

CONTENT OF FREE FATTY ACIDS IN SOME FATS AND OILS.

Names of Fats and Oils.	Table oils. Fatty acid per cent.	Technical oils. Fatty acid per cent.	Extracted oils. Fatty acid per cent.
Almond oil	0.25–0.40	—	—
Becuiba tallow	—	18.55	—
Candle nut oil, 3 years old	—	56.45	—
Castor oil	0.62–18.61	—	1.18–5.62
Charlock seed oil	—	2.85	—
Cocoanut oil	—	3.03–14.35	—
Cod-liver oil	0.24–1.00	—	—
Cottonseed oil	0.15–0.25	0.42–0.50	—
Hempseed oil	—	0.64–4.82	—
Illipé butter, 3 years old	—	28.54	—
Japanese wax	—	9.25	—
Linseed oil	0.40–1.10	0.41–4.19	—
Mustard seed oil	0.68–1.02	—	—
Niam fat	—	—	14.40–34.72
Olive oil.	1.66	3.87–27.16	—
Palm oil	—	50.82	—
Palm kernel oil	—	3.30–17.65	4.17–11.42
Peanut oil	0.85–3.90	3.58–10.61	0.95–8.85
Poppy oil	0.7–2.86	12.87–17.73	2.15–9.43
Rape-seed oil	0.53–1.82	0.52–6.26	0.77–1.10
Sesamé oil	0.47–5.75	7.17–33.13	2.62–9.71
Train oils.	—	3.00–22.50	—

If besides free fatty acid an oil contains sulphuric acid, the latter has first to be withdrawn from the sample to be examined before weighing off the above-mentioned quantity for the test.

Burstyn's method. The managers of some railroads still prescribe the use of Burstyn's acid-meter for the determination of acid in oils. This instrument indicates the content of free fatty acid in an alcoholic solution of fat.

Although absolutely accurate results cannot be obtained with Burstyn's acid-meter, since, on the one hand, all the oleic acid is not extracted by the alcohol, a portion of it being retained by the oil, and on the other, a portion of the oil and Fremy's acids—see below—pass into solution, it may nevertheless be utilized in practice on account of its simplicity.

To obtain the fatty acid solution, place 100 cubic centimeters of the oil to be tested in a stoppered glass cylinder capable of holding 200 cubic centimeters. Fill up the cylinder to the mark with alcohol of 88 to 90 per cent., shake well, and allow to stand two or three hours, the alcohol will have dissolved out the oleic acid as well as the other fatty acids. The increase in the specific gravity is then determined by testing the upper layer—containing the alcohol and fatty acids—with the acid-meter, a delicate aerometer graduated into 50 degrees, a similar cylinder filled with the original alcohol used being simultaneously examined side by side. From the difference in the specific gravities the content of acid=*acid degree* is then calculated by the aid of a table.

One Burstyn degree=one cubic centimeter normal hydrochloric or normal oxalic acid, and, therefore, corresponds to 1 cubic centimeter of a normal potash solution, and the latter again to 0.28 per cent. oleic acid.

Mineral acids. The presence of *sulphuric acid* in oils is established by shaking the oil with water, allowing to settle, and testing the aqueous fluid with the blue litmus tincture or barium chloride solution, the former being reddened in the presence of sulphuric acid, while the latter produces a white precipitate of barium sulphate.

If the sulphuric acid is present in combination with oleic, palmitic and stearic acids, as so-called Fremy's acids, it cannot be extracted by simple shaking. In this case the oil, together with the water, must for some time be heated, best with the addition of a small quantity of hydrochloric acid, and then tested with barium chloride.

For the *quantitative determination of sulphuric acid*, 100 grammes of the oil are for some time boiled with water, stirring constantly, and in the clear aqueous fluid freed from oil, the sulphuric acid is titrated with decinormal or seminormal potash solution, using litmus or methyl orange as indicator.

The presence of *hydrochloric acid* is established by shaking the oil with very dilute nitric acid (1 acid to 30 water) and adding nitrate of silver to the aqueous fluid. In the presence of hydrochloric acid a white precipitate of chloride of silver is formed.

4. *Mineral oils, Paraffin, Ceresin and Rosin oils in fat Oils and Fats.*

Adulterations, with larger quantities of mineral or rosin oils, can frequently be recognized by the fluorescence, though various means are now used for the removal of the fluorescence and odor characteristic to mineral oils, when the latter are to be used as an addition to vegetable or animal oils. In many cases the mineral oil is rendered lustreless by treatment with small quantities of nitric acid, whereby it acquires a brown color, almost loses its fluorescence, and in this form is especially suitable for the production of artificial fish oil. Recently light-colored mineral oils have been almost deprived of their fluorescence, by a slight addition of nitro-bodies, the nitronaphthalenes being especially suitable for the purpose; the quantity used varies between ½ and 1½ per cent. of the oil. An aniline color, "*jaune anglais*," very probably a chinoline coloring matter, has also recently been used with success. To remove the odor, the mineral oils are chiefly perfumed by the addition of oil of turpentine, nitro-benzole and volatile oils.

Rosemary oil is used especially for oil which is to serve as an addition to degenerated olive oil.

Mineral oils, paraffin and ceresin, are not saponifiable, but rosin oils partially so, so that quantitative determinations of the latter are only approximate.

The quickest way of detecting adulterations is by the saponification method, p. 185, and subsequent determination of the saponification number. The difference between the saponification number—K—belonging to the oil or fat—O—and the saponification number—G—found, gives the intentional addition, and is calculated by simple proportion

$$O = 100 - \frac{100G}{K.}$$

For gravimetric analysis, 5 to 10 grammes of the oil to be tested, together with 2 or 3, or 4 or 6 grammes of sodium hydrate and 30 to 40 or 60 to 80 cubic centimeters of water, are heated on a water bath, and to accelerate saponification, 15 to 20 cubic centimeters of alcohol added. Rosin and mineral oils, if present in larger quantities, float upon the resulting soap paste while, if present in smaller quantities, they remain suspended in it. To convert the excess of sodium hydrate into simple sodium carbonate, add about 1 gramme sodium bicarbonate, evaporate the whole to dryness, first adding a small quantity of coarse gravelly sand, and extract the residue with ether or petroleum-ether. The extracts are collected in a tared flask, the ether is distilled off and the residue weighed; the latter contains the non-saponifiable rosin or mineral oil, paraffin, etc.

It is of advantage to evaporate to dryness, because by shaking the soap paste with petroleum-ether the mass swells up to 5 or 6 volumes, and the petroleum-ether separates very slowly, though somewhat more rapidly after adding an equal volume of alcohol, a small quantity of coarse sand and of common salt. If the mass has not been evaporated to dryness, and is to be extracted with ether, the alcohol has to be entirely driven off. For clarifying the layers glycerin is added, as well as a small quantity of sand, the latter contributing materially to the separation of the soap.

To determine whether the residual oil is *rosin or mineral oil*, a sample in a test-tube is heated to boiling with an equal volume of nitric acid of 1.185 to 1.20 specific gravity. Rosin oil is strongly attacked, and shows a characteristic rosin-odor in connection with nitrous acid vapors, while mineral oil is not attacked. Towards anhydrous chloride and bromide of tin, rosin oil exhibits a peculiar behavior. If 10 drops of the oil in question are stirred together with one drop of the tin combinations, a purple coloration appears.

5. *Mineral oil in rosin oil.*

For the detection of mineral oil in rosin oil, Finkener makes use of the difference in solubility of the two oils in a mixture of 10 volumes of alcohol of specific gravity 0.812 at 60° F., and 1 volume of chloroform.

Rosin oils, on shaking with 10 times the volume of this mixture, dissolve at 73.4° F., while mineral oils with a high boiling point do not dissolve at this temperature with 100 times the volume of the same mixture. Hence, from the undissolved portion which remains behind in mixing one volume of the oil in question and 10 volumes of the chloroform and alcohol mixture, the mineral oil is recognized and may also be quantitatively determined in a graduated cylinder.

To distinguish *mineral oils and rosin oils*, Valenta makes use of glacial acetic acid; rosin oils dissolve in it with ease at 122° F., but mineral oils very sparingly. Ten cubic centimeters of glacial acetic acid dissolve 0.2823 to 0.6849 gramme of mineral oil and 1.7 to 2 grammes of rosin oil; in mixtures the solubility, however, does not increase proportionately to the content of the rosin oil.

Volumetrically, mineral oil and rosin oil in fat oils may be determined by bringing 20 cubic centimeters of oil or carefully melted fat into a flask of 200 cubic centimeters capacity, graduated into 10 parts, and having a graduated neck holding

20 cubic centimeters divided into $\frac{2}{10}$, and saponifying with 5 grammes sodium hydrate and 20 cubic centimeters alcohol. When saponification is complete sodium bicarbonate is added to convert the caustic soda into sodium carbonate, the flask filled nearly up to the neck with hot water and allowed to stand in a water-bath at 140° to 158° F., for several hours for the separation of the oil. The latter is then forced by hot water into the neck of the flask, and when perfectly cold the non-saponified oil is measured. If rosin oils are present the alcohol has to be completely expelled.

Rosin oils may also be separated from fat oils and mineral oils by their solubility in alcohol, the former being but slightly soluble, and the latter entirely insoluble in alcohol. For an approximate quantitative analysis 20 cubic centimeters of the oil to be examined are brought into a cylinder holding 200 cubic centimeters, and graduated into $\frac{2}{10}$. The cylinder is then filled up to the mark with 90 per cent. alcohol = 0.830 specific gravity, vigorously shaken at intervals, and finally left standing for the contents to clarify. In the presence of rosin oil the volume decreases; the decrease in volume multiplied by 5 gives the percentage of rosin oil. The small quantity of oil dissolved by the alcohol need not be taken into account, since a corresponding quantity of alcohol is absorbed by the oil.

6. *Fat Oils in Mineral Oils.*

Fr. Lux has drawn attention to the fact that after treating mineral oils with soda or caustic soda, the presence in them of even 2 per cent. fat oils suffices to effect solidification of the fluid on cooling by the soap formed.

The saponification of admixed fat oils takes place slowly below 392° F. and best at about 392° F.; at a temperature much above this the soap formed is again decomposed. Heating for 15 minutes is sufficient, and 2 to 5 minutes in the presence of more than 10 per cent. of fat oils.

A. *Preliminary test for the detection of larger quantities of fat oils.*—To about 5 cubic centimeters of the oil in a test-tube add a small piece of sodium hydroxide; heat the liquid directly over the flame to boiling, and keep it boiling for about 1 to 2 minutes. The presence of larger quantities of fat oil is detected by the peculiar empyreumatic smell given off, and by the solidification of the liquid on slightly cooling.

There being seldom less than 10 per cent. of fat oil present, this, in most cases, ends the test. If a negative result is, however, obtained, proceed as follows:

B. *Detection of smaller quantities of fat oils (to 2 per cent.)*—Take two medium-sized beakers, of which the one can be pushed into the other so as to leave a space of about 1 to 2 centimetres between the two. Into the larger beaker place enough melted paraffin to bring its surface, when the narrower beaker is pushed into the larger, half-way up between the sides of the two beakers. Then fill the inside beaker with paraffin to the same height. Fluids in test-tubes placed in a paraffin-bath thus constructed cannot be overheated. A thermometer hung in the inner beaker indicates the temperature, which is to be maintained at from 392° to 410° F.

Now supply two test-tubes with a few cubic centimeters of oil; add to the one some shavings of sodium, and to the other a small stick of sodium hydroxide, so that the latter is covered by about 1 centimeter of oil.

Place the two test-tubes in the paraffin-bath and note the time; allow them to remain quietly for 15 minutes, then take them out, and, after freeing them from paraffin, let them cool.

In the presence of as much as 2 per cent. of fat oil, the sample in one of the two test-tubes, or generally in both, congeals to a tough jelly, which does not run out by turning the tubes upside down, and can only be detached from them by a smart tap. For the quantitative determination of fat oils in mineral oils the saponification method, p. 185, is used.

7. *Soaps in Oils and Fats.*

To increase their viscosity, vegetable as well as mineral oils are mixed with alkaline or earthy soaps—alumina, lime, magnesia soaps. For the detection of such adulterations treat 10 to 20 grammes of the oil or fat to be examined with ether free from alcohol. The soap remaining undissolved is collected upon a weighed filter and washed with ether. The filter is then slowly dried at 122° to 140° F., and weighed together with the residue, which indicates the quantity of soap. The ethereal solution is brought into a tared Erlenmeyer flask, the ether distilled off, and the residue weighed; it is later on tested as to its properties in the manner given on p. 218, in order to determine whether it is a fat oil or mineral oil, or a mixture of both. The residue upon the filter is treated with dilute nitric acid, the fatty acids are filtered off and the solution treated with ammonia. If a white gelatinous precipitate is formed, it is due to alumina, which is filtered off. To one-third of the filtrate sodium phosphate is added, and to another third, ammonium oxalate; a white precipitate indicating in the first case *magnesia* and in the second *lime;* should both be present, the lime in the third portion is precipitated with ammonium carbonate and the filtrate tested as above for magnesia. If no precipitate is formed, the soap in question is an alkaline soap.

For the determination of earthy soaps the respective oil may also be directly shaken with dilute nitric acid and tested in the manner given above.

In very rare cases a *lead soap—lead plaster*—is used for the purpose of adulteration. Its presence is readily detected by a black color formed on adding a few drops of ammonium sulphide to the oil.

Alkaline, as well as earthy alkaline *rosin soaps*, being soluble in ether and alcohol, the method of separation given above is not available, and the oil, etc., has to be extracted with 90 per cent. alcohol and the residue of the alcoholic solution weighed.

Even *resins* are used for thickening, which may, however, be detected by the organoleptic method, or by extracting the oil with alcohol and mixing the solution with alcoholic lead acetate solution, the latter in the presence of resins causing a clotted precipitate, but only turbidity in the presence of rosin oils.

8. *Determination of the Drying and Non-Drying Portions of an Oil.*

By 15 to 20 per cent. disulphide of chlorine drying oils are converted into a caoutchouc-like mass unalterable in acids, dilute lyes and carbon disulphide, a similar reaction not taking place with non-drying oils. Upon this behavior, previously observed by Rochleder, P. Bruce Warren has based a process for separating the drying or non-drying portions of an oil.

Weigh off 5 to 10 grammes of oil in a porcelain dish, add two cubic centimeters of carbon disulphide free from sulphur and the same quantity of a mixture of disulphide of chlorine and carbon disulphide, and heat the whole on a water-bath until a portion or the entire mass has become solid. The solvent is then removed and the caoutchouc-like mass washed with carbon disulphide. The remainder of carbon disulphide is then driven off, and the caoutchouc-like residue weighed. The difference between the oil used and the residue gives the drying and non-drying portions.

B. *Special Methods.*

The methods of examining oils, fats, etc., as to their special properties, the various commercial varieties and principal adulterations, could not be well given in this general chapter, and will be mentioned in speaking of the separate oils.

The adulterations are in conformity with the prevailing prices of the oils, etc., only a cheaper oil being of course taken for sophisticating the principal oil. In some cases, however, a more expensive oil is used in order to impart to the principal oil special properties as regards lubricating power, for instance, mixing mineral oil with colza oil; but, on the other hand, colza oil used for illuminating purposes is, as a rule, adulterated with mineral oil.

The price of oils varies very much according to the crops and the demand, but there is nevertheless a certain stability, and their commercial value may, according to Allen-Duggan, be arranged as follows:

1. Olive oil.
2. Sperm oil.
3. Neat's foot oil.
4. *a*. Herring-dog oil.
    b. Lard oil.
    c. Castor oil.
5. Cod-liver oil.
6. *a*. Peanut oil.
    b. Sesamé oil.
    c. Poppy oil.
7. Colza oil.
8. Seal oil.
9. Niger oil.
10. Linseed oil.
11. Right whale oil.
12. Cotton-seed oil.
13. Menhaden oil.
14. Japanese cod liver oil.
15. Mineral oils.
16. Rosin oils.

For the determination of the purity of an oil, the physical properties, p. 40 to p. 99, are first determined; next, the qualitative methods, p. 172 to p. 184, are executed; and later on, the quantitative methods, p. 185 to p. 223. Of the quantitative determinations, Hübl's iodine number is the most frequently employed.

CHAPTER VIII.

DIVISION OF FATS AND OILS.

THE fats were formerly simply known as animal and vegetable fats, and later on they were distinguished according to their consistency, and divided into fluid fats or fat oils, and expressed fats or fixed oils. The former were again divided into drying and non-drying fat oils and train oils, according to whether they dried on exposure in thin layers to the air, or remained viscous, and the latter into fixed oils, or greases and butters, remaining soft at an ordinary temperature, and solid fixed oils, or tallows and waxes.

The meaning of "ordinary temperature," which ranges at an average between 59° to 72.5° F., is very indefinite, and therefore not a characteristic term for greases and butters, which are soft at an ordinary temperature. Of two different varieties of pure butter or pure lard, one may be solid and the other soft at the same temperature. Butter is solid at 59° F., but becomes soft as grease by the rise of a few degrees in the temperature; bay or laurel oil shows the same behavior. The greases become fluid a few degrees above 68° F., tallows above 86° F., and waxes over 140° F.

A division of the fats according to their physical properties offers no advantage, and a division according to their chemical composition presents also difficulties, since there is not a single fat which is a simple organic compound, but each of them is a mixture of several such compounds to which the term glycerides is applied. In modern times the fats are therefore divided, according to the prevalence of one or the other glyceride, into—

1. LIQUID FATS OR OILS
    - a. *Glycerides of oleic acid, etc. = non-drying oils.*
    - b. *Glycerides of linoleic acid, etc. = drying oils.*
    - c. *Glycerides of physetoleic acid, etc. = train oils.*
2. SOLID FATS.
    - a. *Glycerides of palmitic aeid, etc. = greases and tallows.*
    - b. *Non-glycerides = waxes.*

Glycerides of oleic acid.—The glycerides of oleic acid and allied acids represent the non-drying oils. In a purified state, *i. e.*, free from mucus, albumen, gluten, etc., they undergo but little change by contact with atmospheric air; by long exposure they turn rancid, acquire a disagreeable odor, and become viscous. They do not dry, even if spread in a very thin layer upon wood or other porous substance.

By treatment with nitrous acid or hyponitric acid these oils solidify by the molecular conversion of the olein to elaïdin.

Pure mercurous nitrate does not change the oils.

Castor oil, generally classed among drying oils, very likely belongs to the non-drying oils, since the behavior of ricinolein and ricinoleic acid (see pages 137 and 157) on treatment with nitrous acid corresponds with that of olein and oleic acid, *i. e.*, ricinelaïdin and ricinelaïdic acid are formed with simultaneous solidification. Even in very thin layers castor oil only dries incompletely after months of exposure. It forms, like the train oils, a transition grade from the non-drying to the drying oils.

The doubtful oils are marked with a star (*).

A. *Oils of the Vegetable Kingdom.*

Name of the Family.	Name of the Oil.	Name of Species.
Cæsalpiniaceæ,	Pea-nut oil,	Arachis hypogæa.
"	Ben oil,	Moringa oleifera, etc.
Amygdaleæ,	Almond oil,	Amygdalus communis.
"	Peach-kernel oil,	" persica.
"	Plum-kernel oil,	Prunus domestica.
"	Cherry-kernel oil,	" cerasus.
Pomaceæ,	Apple-seed oil,	Pyrus malus.
"	Quince seed oil,	Cydonia vulgaris.
Cassuvieæ,	Cashew-apple oil,	Anacardium orientale.
Celastrineæ,	Spindle-tree oil,	Evonymus europæus.
Euphorbiaceæ,	Croton oil,	Croton tiglium, etc.
"	* Castor oil,	Ricinus communis.
"	* Spurge oil,	Euphorbia lathyris.
"	* Purgir-nut oil,	Jatropha curcas.
Hypocastaneæ,	Horse-chestnut oil,	Æsculus hypocastanum.
Malvaceæ,	* Cotton-seed oil,	Gossypium species.
"	"	Bombax species.
Camelliaceæ,	Tea-seed oil,	Thea oleosa, etc.
Myrtaceæ,	Brazil or Para-nut oil,	Bertholletia excelsa.
Combretaceæ,	Jungle-almond oil,	Terminalia catappa.
Cruciferæ,	Rape-seed oil,	Brassica species.
"	Colza oil,	" "
"	Mustard-seed oil,	Sinapis species.
"	Radish-seed oil,	Raphanus sativus.
Bignogniaceæ,	Sesamé oil,	Sesamum species.
Oleaceæ,	Olive oil,	Olea europæa.
Cupuliferæ,	Beech-nut oil,	Fagus sylvatica.
"	Hazel-nut oil,	Corylus avellana.
Gramineæ,	Maize oil,	Zea mais.
Cyperaceæ,	Cyperus oil,	Cyperus esculentus.

B. *Oils of the Animal Kingdom.*

Name of the Family.	Name of the Oil.	Name of Species.
Solidungula,	Horse's-foot oil,	Equus caballus.
Ruminantia, Cavicornia,	Neat's-foot oil,	Bos taurus.
"	Sheep's-trotter oil,	Ovis aries.
Gallinæ,	Egg oil,	Gallus domesticus.

Glycerides of Linoleic acid.—The glycerides of linoleic acid and allied acids are only found in the vegetable kingdom and form the group of drying oils.

They differ from the glycerides of oleic acid in that they absorb a considerable quantity of oxygen, but yield carbon and hydrogen in the form of carbonic acid and water, while the original oil is converted into a combination far richer in oxygen. The drying oils do not become rancid in the same sense as non-drying oils, though in drying they also acquire a disagreeable odor.

Cloëz has found that on exposure to the air all fat oils absorb oxygen. He observed for 18 months the absorption of oxygen—increase in weight—of 10 grammes each of drying as well as of non-drying oils, and found the increase as follows:

ABSORPTION OF OXYGEN BY FAT OILS.

10 grammes drying oil.	Increase grammes.	10 grammes non-drying oil.	Increase grammes.
Camelina	0.810	Almond	0.459
Candlenuts	0.742	Apricot kernel	0.547
Hempseed	0.778	Castor	0.268
Horned poppy	0.696	Colza	0.566
Linseed	0.703	Hazelnut	0.434
Madia	0.699	Mustard seed	0.527
Poppy	0.705	Peanut	0.462
Pumpkin seed	0.740	Radish seed	0.537
Sunflower seed	0.689	Sesamé	0.483
Walnut	0.747	Spindle tree	0.391

Light exerts a considerable influence upon the absorption of oxygen by the drying oils; while the process is very slow in the dark, it is most quickly accomplished in a blue or colorless light, and less quickly in a red, yellow, and green light.

Cloëz found that the weight of oxygen in ten grammes of poppy-seed oil increased—

	In 40 days.	In 150 days.
In the dark	0.008 grammes.	0.638 grammes.
Colorless glass	0.520 "	0.498 "
Red glass	0.322 "	0.726 "
Yellow glass	0.471 "	0.733 "
Green glass	0.307 "	0.786 "
Blue	0.613 "	0.618 "

Drying oils are not solidified by contact with nitrous or hyponitric acid.

Oils marked with a star (*) are doubtful.

Name of the Family.	Name of the Oil.	Name of Species.
Euphorbiaceæ,	Candle-nut oil,	Aleurites moluccana.
Ampelideæ,	Grape-seed oil,	Vitis vinifera.
Lineæ,	Linseed oil,	Linum usitatissimum.
Cucurbitaceæ,	Pumpkin-seed oil,	Cucurbita species.
"	Koëme oil,	Telfairia pedata, Hook.
Cruciferæ,	Hesperis oil,	Hesperis matronalis.
"	Cress-seed oil,	Lepidium sativum.
"	Camelina oil,	Camelina sativa.
Papaveraceæ,	Poppy-seed oil,	Papaver somniferum.
"	Horned poppy-seed oil,	" glaucum.
Resedaceæ,	Weld-seed oil,	Reseda luteola.
Solaneæ,	*Tobacco-seed oil,	Nicotiana tabacum.
"	*Belladonna oil,	Atropa belladonna.
"	*Henbane-seed oil,	Hyoscyamus niger.
Compositæ,	Sunflower-seed oil,	Helianthus annuus.
"	Madia oil,	Madia species.
"	Thistle-seed oil,	Onopordon acanthium.
Urticeæ,	Hemp-seed oil,	Cannabis sativa.
Juglandeæ,	Nut oil,	Juglans regia.
"	"	Carya illinoënsis.
Coniferæ,	Red pine-seed oil,	Pinus abies.
"	Scotch fir-seed oil,	" sylvestris.

Glycerides of physetoleic acid.—The glycerides of physetoleic acid* and allied acids are only found in the animal kingdom, and form the group of fish oils or train oils.

Train oils do not dry in the air, but become more viscous. As regards their physical properties, they are intermediate between non-drying and drying oils.

All train oils have a peculiar odor and taste, and contain certain animal substances which render them unfit for burning oils. They are, however, extensively used in the manufacture of soap, in tawing, etc.

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* Hypogæic acid, which is identical with physetoleic acid, is found in peanut oil.

Name of the Family.	Name of the Oil.	Name of Species.
Mammalia, Pinnipedia,	Walrus oil,	Trichechus rosmarus.
" "	Seal oil,	Phoca vitulina.
" Cetacea,	Black-fish oil,	Delphinns globiceps.
" "	Spermoil,	Physeter macrocephalus.
" "	Spermaceti oil,	" "
" "	Right whale oil,	Balæna antarctica.
" "	Herring-dog oil,	" rostrata.
Pisces, Gadini,	Cod-liver oil,	Gadus morrhua, etc.
" "	" "	" lota, etc.
" Raiacei,	Ray oil,	Raia clavata, etc.
" Clupeacei,	Ordinary fish oils,	Clupea species.

Glycerides of Palmitic and Stearic Acids.—The glycerides of palmitic and stearic acids and allied acids form the group which in the language of ordinary life are termed "fats." The soft varieties are called *grease* or *butter*, and the harder ones *tallow*.

A. *Solid Fats of the Vegetable Kingdom.*

Name of the family.	Name of the Fat.	Name of Species.
Burseaceæ,	Dika fat,	Irvingia Barteri.
Euphorbiaceæ,	Chinese tallow,	Stillingia sebifera.
Meliaceæ,	Carapa oil,	Carapa Tolucana.
Dipterocarpeæ,	Piney tallow, Malabar tallow,	Vateria indica.
Büttneriaceæ,	Cacao butter,	Theobroma cacao, etc.
Terebinthaceæ,	Japanese tallow (wax),	Rhus succedanea.
Clusiaceæ,	Kokum fat or Goa butter,	Brindonia indica = Garcinia indica.
Myristiceæ,	Nutmeg butter,	Myristica moschata.
"	Otoba butter,	" Otoba.
"	Ocuba tallow (wax),	" Ocuba.
"	Becuiba tallow,	" officinalis.
"	Virola tallow,	Virola sebifera.
Sapoteæ,	Shea butter or Galam butter,	Bassia species.
Laurineæ,	Laurel butter,	Laurus nobilis.
"	Laurel tallow,	Tetranthera laurifolia.
"	Tongkallak fat,	Lepidedania Wigh = Cylicodaphne sebifera.
Palmæ,	Cocoanut oil,	Elais guianensis, etc.
"	Palm oil,	Astrocaryum vulgare.
"	"	

B. *Solid Fats of the Animal Kingdom.*

Name of the Family.	Name of the Fat.	Name of Species.
Multungula, Setigera,	Lard,	Sus scrofa.
Solidungula,	Horse (neck) fat,	Equus caballus.
Ruminantia, Cavicornia,	Butter,	Bos taurus.
"	Ox tallow,	" "
"	Ox marrow,	" "
"	Sheep tallow,	Ovis aries L.
Aves, Palmipedes,	Goose grease,	Anas anser dom.

Non-glycerides.—The non-glycerides, *i. e.*, the waxes, belong, like the preceding groups, to the compound ethers or esters of the fatty acids. They contain, however, less of the triatomic alcohol glycerin and more of the primary alcohols, for instance, cetyl alcohol, ceryl alcohol, etc.

Waxes have a firmer consistency than tallows, and a considerably higher melting point.

A. *Waxes of the Vegetable Kingdom.*

Name of the Family.	Name of the Wax.	Name of Species.
Artocarpeæ,	Fig wax,	Ficus ceriflua.
Myriceæ,	Myrtle-berry wax,	Myrica cerifera.
Palmæ,	Carnauba wax,	Corypha cerifera.
"	Palm-tree wax,	Ceroxylon andicola.

B. *Waxes of the Animal Kingdom.*

Name of the Family.	Name of the Wax.	Name of Species.
Hymenoptera,	Bees' wax,	Apis mellifica.
Hemiptera,	Chinese wax,	Coccus ceriferus.
Mammalia, Cetacea,	Spermaceti,	Physeter macrocephalus.

The descriptions, properties, adulterations, etc., of the various oils and waxes will be found in Chapter XV.

CHAPTER IX.

CLEANING AND STORING OIL SEED.

PREVIOUSLY to being brought into commerce or subjected to expression, the oil seed has to be freed from sand, earth, vegetable admixtures—stems, etc.—and foreign seed, the latter imparting a disagreeable taste to the press-cake, while by the admixture of sand and earth not only the machinery is worn out, but the oil cake deteriorates, and becomes poorer in nutriment.

The separation of admixtures of foreign bodies specifically lighter than the oil-seed itself is effected by means of a fan. The effects produced by the foreign seed which remains after fanning varies and may be distinguished as follows:

1. Seeds which furnish oil themselves and hence do not diminish the yield, but the oil is contaminated with foreign oil, for instance, linseed oil with hedge radish oil, mustard-seed oil or camelina oil, the plants from which these oils are derived being troublesome weeds in the cultivation of flax.

2. Seeds which, while not yielding oil, contain enough of it to prevent them from absorbing oil during expression and hence increase only the weight or volume, for instance, the seeds of *Polygonum persicaria* (spotted knotweed or lady's thumb) and *Polygonum lapathifolium* (water pepper).

3. Seeds which contain no oil, or at least only minute quantities of it, and hence in pressing absorb oil, consequently diminishing the yield, for instance, the seeds of *Lolium arvense* and *L. temulantum* (darnel).

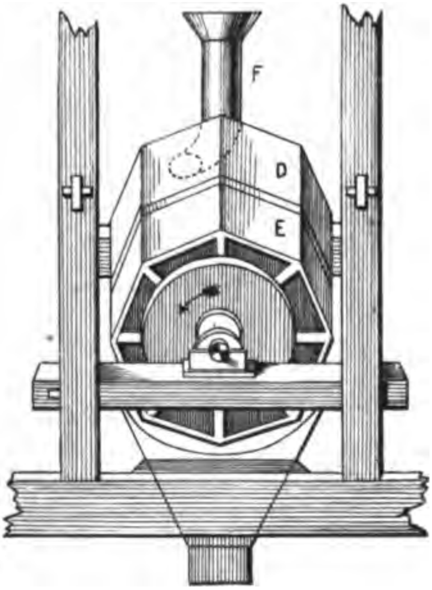
To the third division belong further the troublesome admixtures of earthy and clayey particles, they also absorbing oil.

In cleaning oil seed, it has therefore to be observed whether the impurities to be separated are

1, of the same size as the seed to be cleaned;
2, or smaller, and
3, or larger.

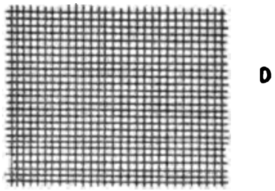
The first are the most difficult to remove, since they remain among the seed, except they can be comminuted upon the screen—for instance, small lumps of earth, etc. The others are removed by screens set into oscillatory motion. The cylinder shown in Figs. 37 to 40 is most suitable for the purpose. It has a six or eight-cornered cross-section, is 26 to 32 inches in diameter, about 6 feet long, and from *C* to *A*, Fig. 40, has a fall of $\frac{3}{4}$ to 1 inch per running foot. It is set in motion by a six or eight-cornered shaft, the pivots of which rest in cast-iron pillow blocks. On the upper pivot is the pulley *B*. For about 3 feet from the top the wooden frame of the drum *C* is covered with a fine iron screen *D*, Fig. 38 (1 wire to the millimeter), and the remainder with a coarser screen *E*, Fig. 39 (1

FIG. 37.



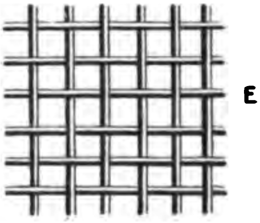
CLEANING CYLINDER, FRONT VIEW.

FIG. 38.



SCREEN.

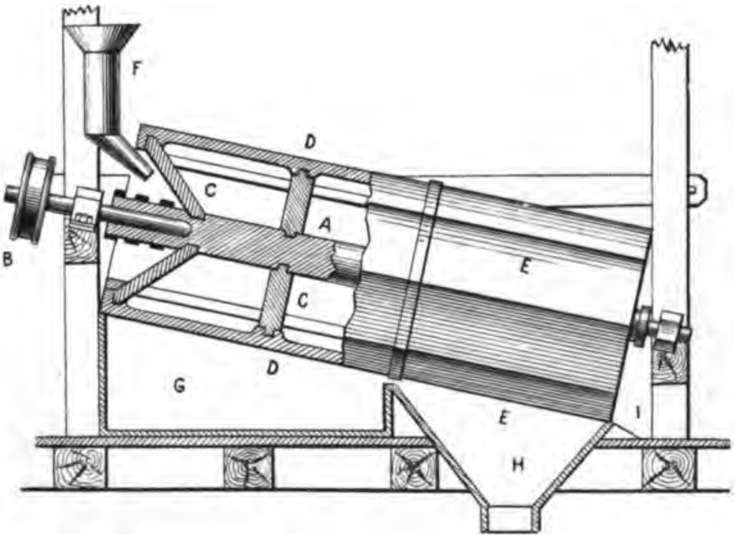
FIG. 39.



SCREEN.

wire to 3.7 millimeters). The hopper *F*, Fig. 37, for the introduction of the seed, is marked in the cylinder by dots. It is bent in the direction of the motion of the cylinder as indicated by arrows. The cylinder is so placed in a room that the dust created is carried off by a current of air. For working, the cylinder requires a power corresponding to ¼ horse power. It makes 40 revolutions per minute, and in 1 hour cleans 64 to 72 bushels of rape-seed.

FIG. 40.



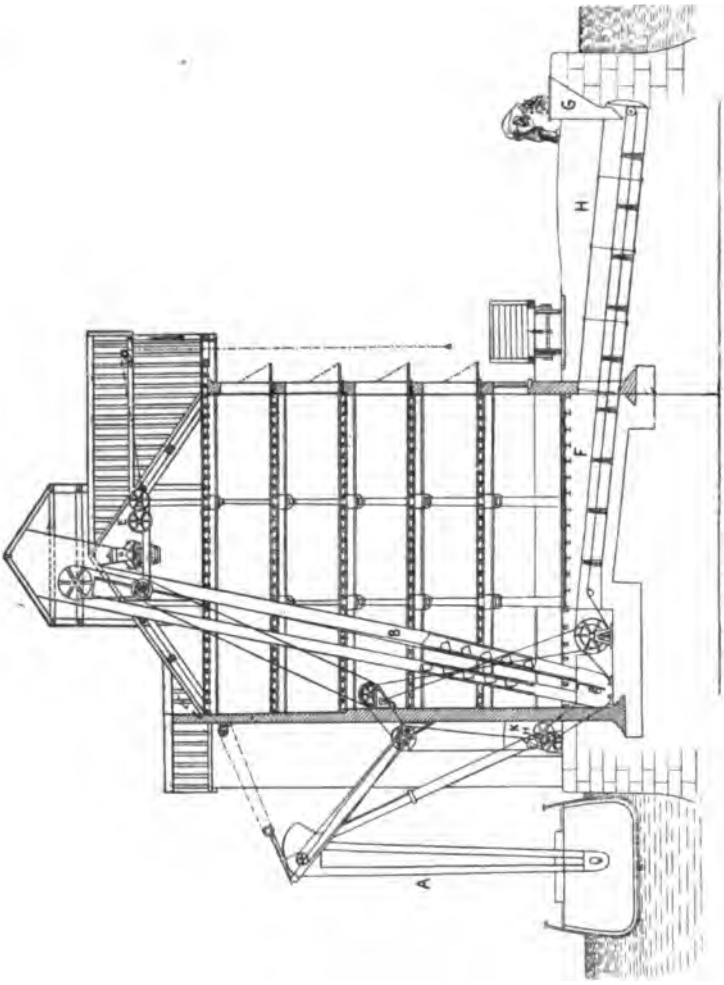
CLEANING CYLINDER: SIDE VIEW AND SECTION THROUGH THE CENTER.

A, wooden shaft; B, pulley; C, wooden frame of the drum; D, fine screen; E, coarse screen; F, hopper for the introduction of seed; G, box for dust, etc.; H, spout for cleansed seed; I, place where the coarser contaminations are deposited.

With very dirty seed, the fall per running foot of the cylinder is diminished and the velocity doubled.

The *storage of oil* seed requires considerable attention. When fresh, the seed should be spread out upon the floor of the store house in piles not more than 3 inches high, otherwise it becomes readily musty and mouldy. There should be sufficient ventilation to constantly renew the air impregnated with moisture, but without exposing the seed to the action of wind and weather. For rapid drying the piles should be turned over with a shovel twice a day. When completely dry the seed may be piled up 1 foot high in summer, and 2 feet high in winter; the piles must, however, be turned up with the shovel at least once or twice a week, because the seed reab-

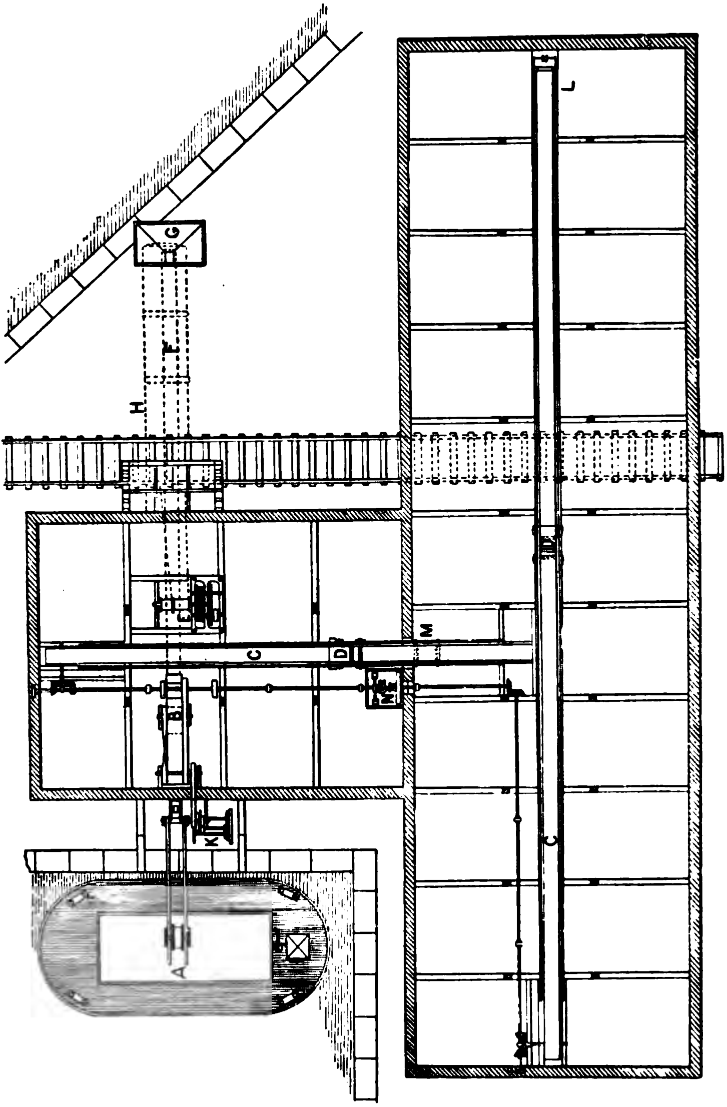
FIG. 41.



SEED-ELEVATOR: SIDE VIEW.

sorbs moisture from the air, and is again exposed to the danger of becoming mouldy. By the absorption of much moisture from the air the seed becomes heated in the pile, commences to get sticky and cakes together. Spontaneous heating of the

FIG. 42.



SEED-ELEVATOR: GROUND PLAN.

1. Percentage of water, which varies from 5 to 10 per cent.

2. Substances extractable by water, such as sugar, gum, mucus, which amount to about 12 to 25 per cent.

3. Substances extractable with ether (oil, resin), which vary much.

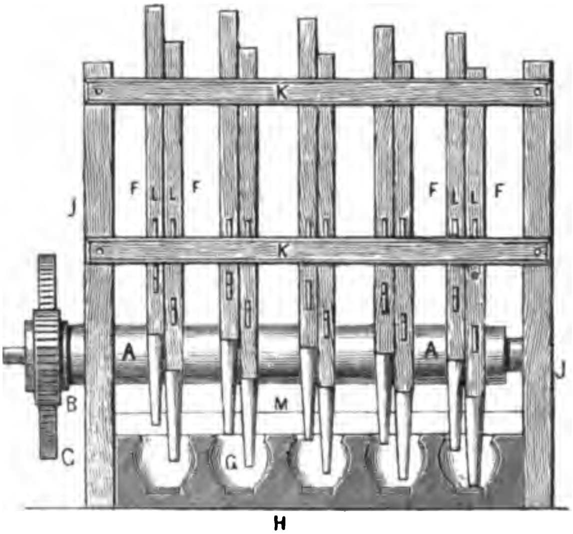
4. Substances insoluble in water and ether (cellulose, etc.), amounting to about 7 to 15 per cent., and

5. Content of ash, which varies between 3 and 12 per cent.

For crushing the shells and comminuting the seeds, the following arrangements are chiefly used:

1. Stamping mill.
2. Rolls.
3. Millstones or runners.

FIG. 43.

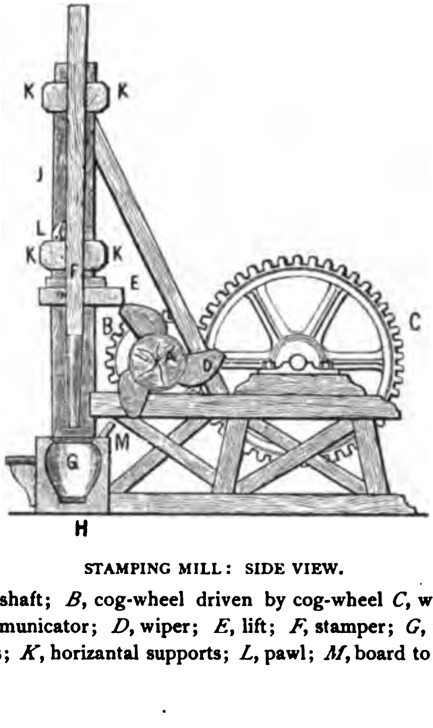


STAMPING MILL: FRONT VIEW.

Stamping mills were formerly exclusively used, but at present they are seldom found, and then only in small oil mills. A stamping mill (Figs. 43 and 44) consists of three principal parts: the cam-shaft, stampers or pestles and their frames, and the mortars.

The oaken cam-shaft, *A*, which is set in motion by the cog-wheels, *B* and *C*, must be strong enough not to bend under the load resting upon it nor from the motion of the stampers. It is provided with the wiper, *D*, which, when the shaft is set in motion, catches under the lift, *E*, and raises the stamper, *F*.

FIG. 44.



STAMPING MILL: SIDE VIEW.

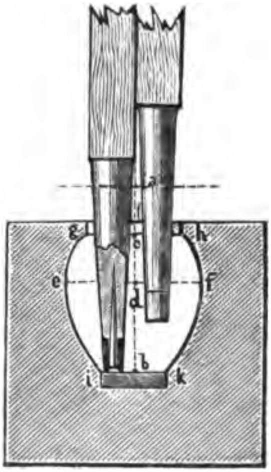
A, horizontal cam-shaft; *B*, cog-wheel driven by cog-wheel *C*, which sits upon the shaft of the communicator; *D*, wiper; *E*, lift; *F*, stamper; *G*, mortar; *H*, mortar bed; *J*, columns; *K*, horizantal supports; *L*, pawl; *M*, board to prevent scattering of seed.

The wipers are so distributed upon the cam-shaft that the stampers are not raised all at once, but in a determined succession and at equal intervals. While emptying or filling the mortars, the action of the stampers is suspended by the pawl *L*. To prevent scattering of seed in filling and emptying, a board, *M*, is placed upon the mortar bed back of the stamping mill, while another board for holding the boxes for the reception of the crushed seed is placed in front of the mortar bed, *H*.

The stampers, of hard wood and best shod with iron, weigh each about 144 pounds, and should never be less than 120 pounds.

The mortars, *G*, should be shaped as shown in Fig. 45, and must be large enough so that, when properly filled, there is sufficient room for the stamper without scattering seed. On the bottom of each mortar is an iron plate fastened with screws, upon which the stamper falls.

FIG. 45.



STAMPING MILL: FORM OF MORTAR.

The mortars are constructed as shown in Fig. 45:

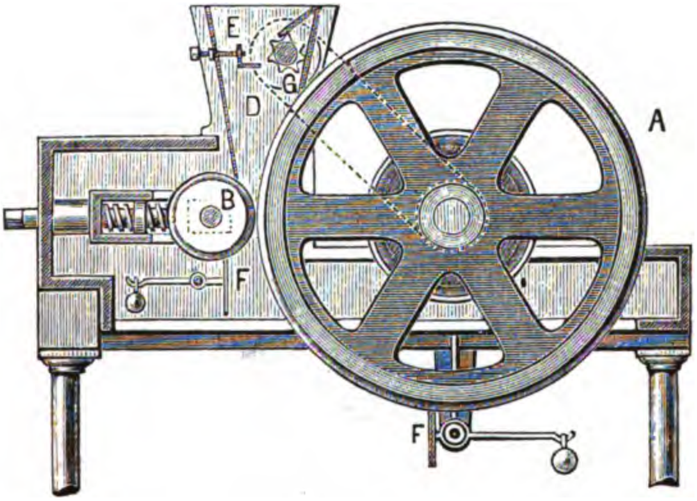
$a\,b$ hub,
$b\,c = \frac{3}{4}\,a\,b$,
$c\,d = \frac{1}{3}\,b\,c$,
$d\,e = d\,f = c\,d$,
$e\,g$ and $f\,g$ arcs of a circle around the centre d,
$c\,i$ and $f\,k$ arcs of a circle around the centre of f and e,
$c\,l = 33$ millimetres (1.29 inches).

The stamping mill is generally driven by water power; the operation is very simple, and requires no further explanation. By the heat developed by continuous stamping, the seed-meal becomes also heated, which is recognized by vapors arising from the mortars. The mass is then sprinkled with water, which not only cools the meal, but facilitates the subsequent expression of the oil.

Rolls.—In all recent oil mills the stamping mill is superseded by rolls. Figs. 46 and 47 illustrate crusher rolls.

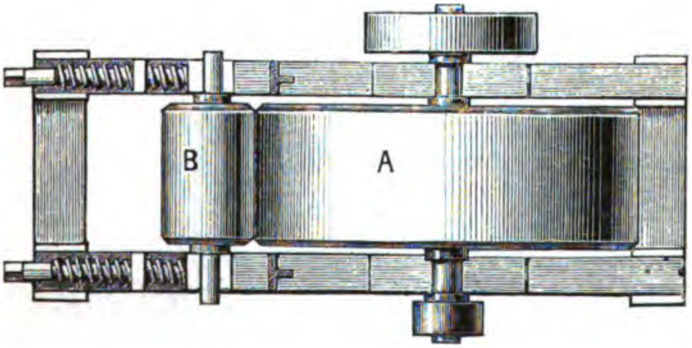
The cleansed seed is conveyed to the crusher roll through the hopper, *D*, by means of the grooved roll, *G*. The slide, *E*, is provided with a screw to regulate the distance between it and the feeding-roll, *G*. The two cast-iron crusher rolls are of different sizes, the diameter of *A* being four times that of *B*.

FIG. 46.



CRUSHER ROLLS: LONGITUDINAL SECTION.

FIG. 47.



CRUSHER ROLLS: GROUND-PLAN.

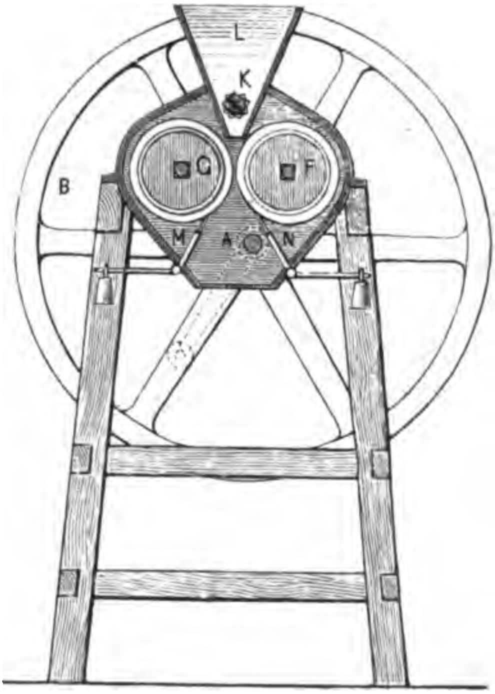
A, large roll; *B*, small roll; *G*, grooved roll in the hopper, *D*; *E*, slide; *F*, scraper.

The distance between the rolls is regulated according to the size of the seed to be crushed. The large roll, *A*, which is put in motion by a pulley and belt, makes fifty-six revolutions per minute, and by friction drives the small roll, *B*, the brasses of which are movable.

Below the rolls are placed the scrapers, *F;* which are pressed against the rolls by a lever and weights, and free them from adhering particles of seed.

A crusher much in use, which, though calculated to be worked by hand, can also be driven by other means after removing the crank, is shown in Figs. 48, 49, 50, and 51.

FIG. 48.



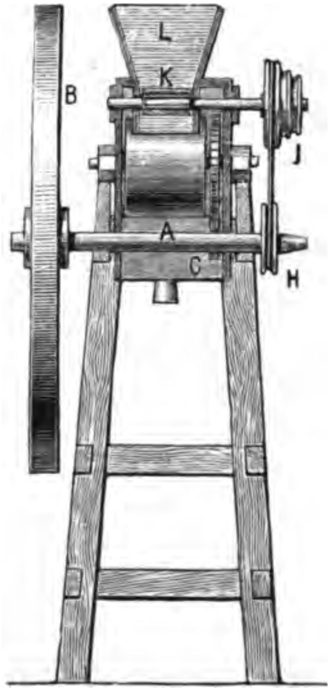
CRUSHER, CROSS SECTION.

A, axle; *B*, fly-wheel; *C*, small driving-wheel upon *A*; *D*, cog-wheel of the one roll; *E*, cog-wheel of the other roll; *G*, *F*, rolls; *H*, band-pulley upon *A*; *J*, band-pulley upon grooved feeding-roll, *K*; *L*, hopper; *M*, *N*, scrapers.

The internal arrangement is illustrated by the cross section, Fig. 48.

Upon the axle, *A*, sits the driving-wheel, *C*, connected with the fly-wheel, *B*. When in motion, *C* catches into the spur-wheel, *D*, which drives the cog-wheel, *E*, whereby the two grooved cast-iron rolls, *G* and *F*, are put in motion. The band-pulley, *H*, upon the axle, *A*, moves at the same time one of the band-pulleys, *J*, which are of different diameters, according to the speed desired. The band-pulleys revolve the grooved feeding-roll, *K*, the object of which is to distribute the seed poured into the hopper, *L*, uniformly upon the rolls *G* and *F*.

FIG. 49.

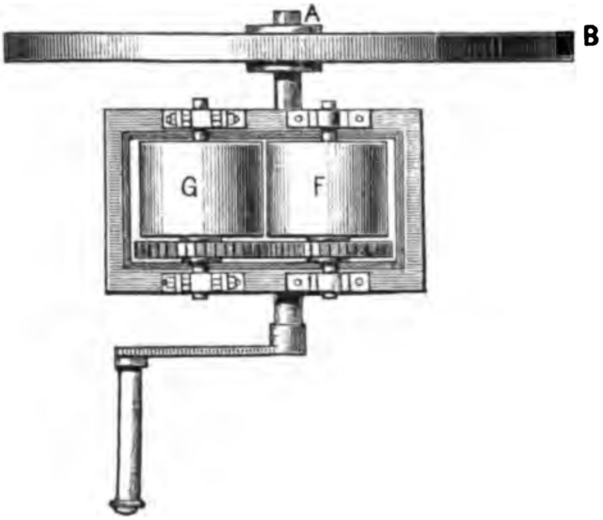


CRUSHER, CUT THROUGH THE CENTRE.

The scrapers *M* and *N* are placed under the rolls, and are pressed against them by a lever and weight.

In the illustration the framework is of wood, but it is now generally of cast-iron. Hollow cast-iron rolls are now used instead of the former solid ones.

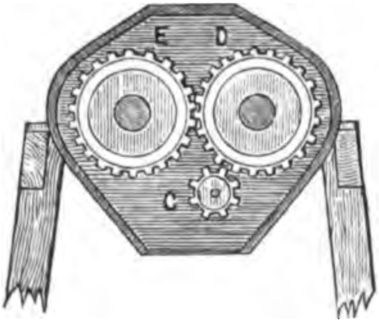
FIG. 50.



CRUSHER, GROUND-PLAN.

The rolls have generally a diameter of 12 inches, but vary very much in length, and make 33 to 60 revolutions per minute.

FIG. 51.

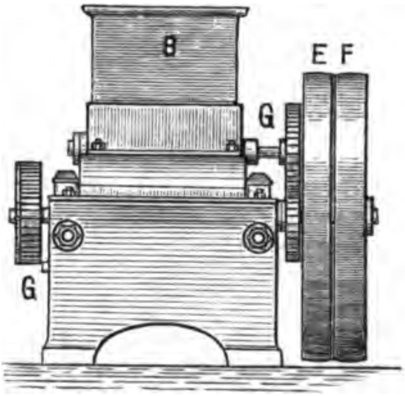


CRUSHER, COG TRANSMISSION.

Figs. 52, 53, and 54, illustrate a steam crusher according to Rigg.

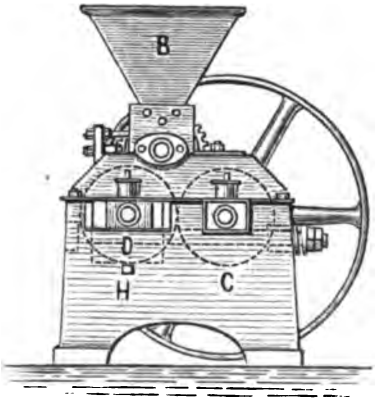
Both rolls have the same diameter. The grooved distributing roll distributes the seed in the hopper *B* upon the rolls *C* and *D*. The quantity to be introduced is regulated by a slide.

Fig. 52.



CRUSHER ACCORDING TO RIGG. FRONT VIEW.

Fig. 53.



CRUSHER ACCORDING TO RIGG. SIDE VIEW.

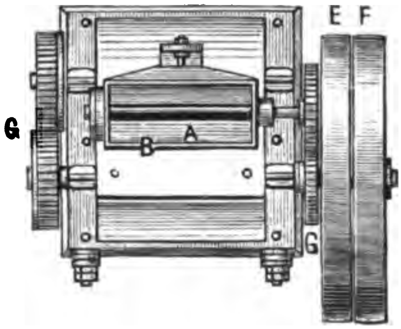
The crusher is put in motion from the principal shaft by means of a belt. Upon the shaft of the one roll sit the fixed pulley

E and the loose pulley *F*, so that the crusher can be readily put in motion or stopped. From this roll-shaft the second roll *D* and the distributing roll *A* are put in motion by the cog-wheels *G*. One of the rolls runs in fixed brasses, while those of the other can be shifted horizontally to regulate the space between the rolls. The movable brasses are connected by two long bolts tightened by strong springs, so that this roll acts with a certain elasticity against the fixed roll, allowing solid substances in the seed to pass through.

The crushed seed is scraped from the solid roll, *D*, by the square scraper blade, *H*.

In some oil mills it is customary to pass the crushed seed a second time through the rolls, placed closer together, before bringing it under the millstones or runners.

FIG. 54.



CRUSHER ACCORDING TO RIGG. GROUND-PLAN.

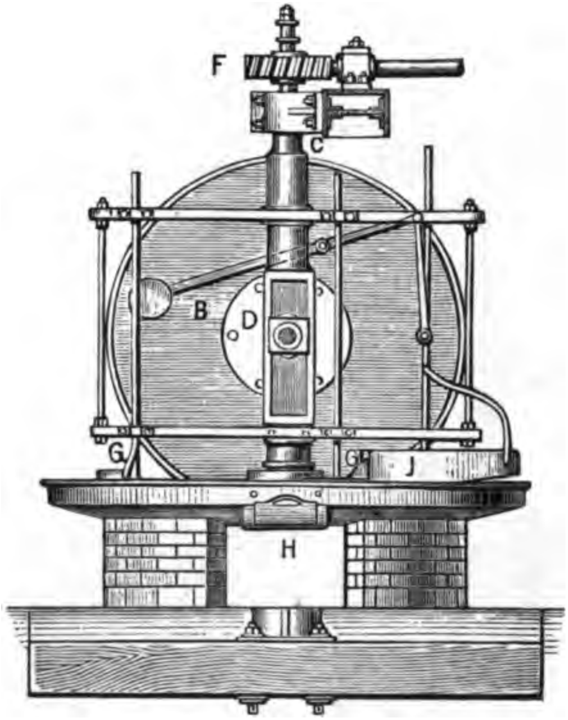
A, distributing roll; *B*, hopper; *C*, roll; *D*, roll; *E*, fixed pulley: *F*, loose pulley; *G*, cog-wheel; *H*, scraper.

Seed difficult to press or old seed is, previously to and during crushing, moistened with a small quantity of water, which, by displacing the oil in the seed, renders the process of extraction much more easy of execution.

Edge runners.—The seed crushed by the rolls is not sufficiently fine, and has to be ground between two vertical granite millstones or runners revolving on a horizontal bed.

Figs. 55 and 56 give two views of a mill. Each stone weighs about five thousand pounds and has a diameter of five feet nine inches. Both the stones *A* and *B* revolve slowly around the vertical shaft *C*, whereby they also revolve around their horizontal shaft *D* and scrape upon the bed *E*. This gives them a grinding and crushing effect and converts the seed into a uniform and extremely fine mass.

FIG. 55.



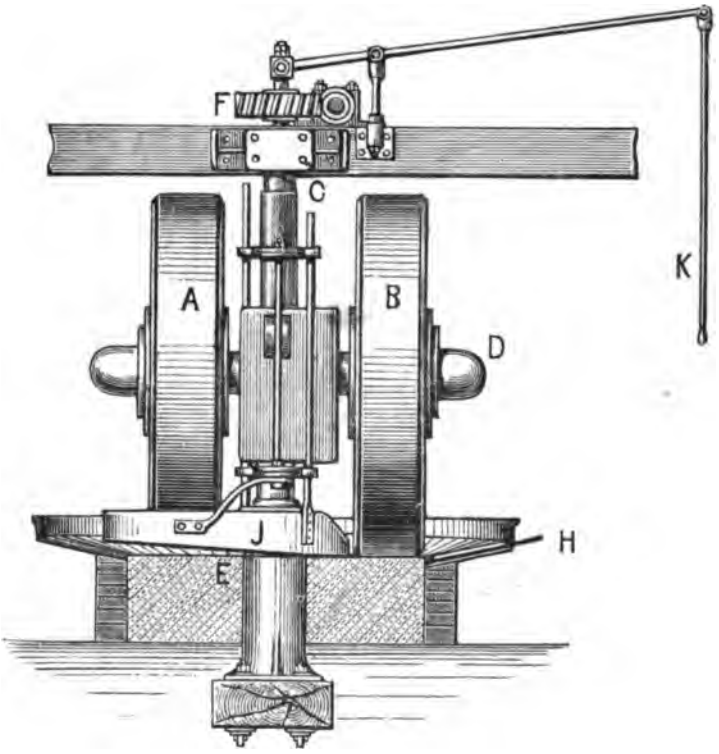
EDGE-RUNNERS. FRONT VIEW.

A, *B*, stones; *C*, vertical shaft; *D*, horizontal shaft; *E*, bed; *F*, worm-wheel; *G*, scraper; *H*, slide; *J*, shovel; *K*, lever.

The vertical shaft *C* is set in motion from the principal shaft by means of the worm-wheel *F*. Two scraper blades, resting with their weight upon the bed *E*, revolve with the stones; one serves to brush the seed forced to the outer edge by the stones back to the interior, and the other to return the seed pushing towards the centre into the track of the runners. These functions are effected by the peculiar curve of the scrapers.

When the seed is sufficiently ground it is removed by opening the slide, *H*, and allowing the crescent-shaped shovel, *J*, held by the lever, *K*, to fall upon the bed.

Fig. 56.



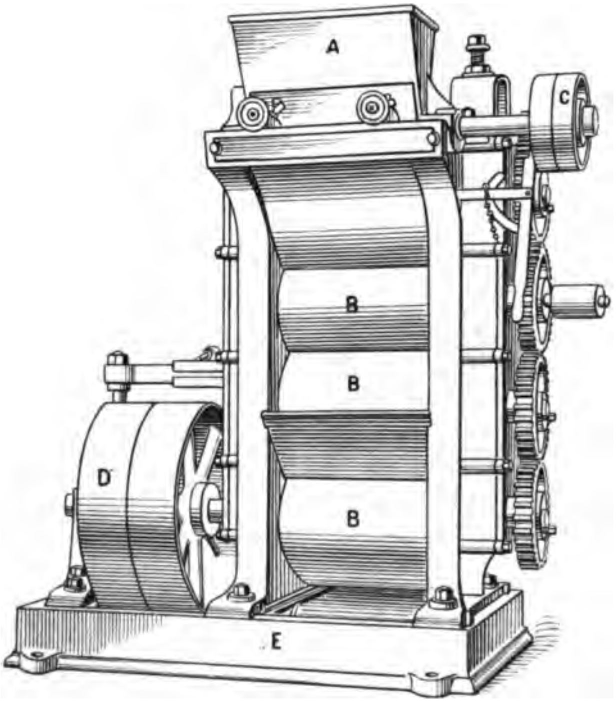
EDGE RUNNERS. SIDE VIEW.

In grinding the seed under the millstones it is also necessary to moisten it.

Some manufacturers press the spontaneously heated meal without preparatory heating.

The most modern constructions of crushing rolls avoid the troublesome and time-consuming comminution of the seed between ordinary rolls and edge-runners; the seed by being passed successively through a number of rolls is ground sufficiently fine to allow of its being immediately subjected to pressure. A type of these crushing rolls is shown in Fig. 57. It consists of four superposed roll about 16 inches in diameter and 42 inches long, so arranged that the seed is delivered from the hopper above between the two uppermost rolls. The delivery from the hopper is effected by means of a fluted feed roller, the same length as the crushing rolls, and a slanting

FIG. 57.

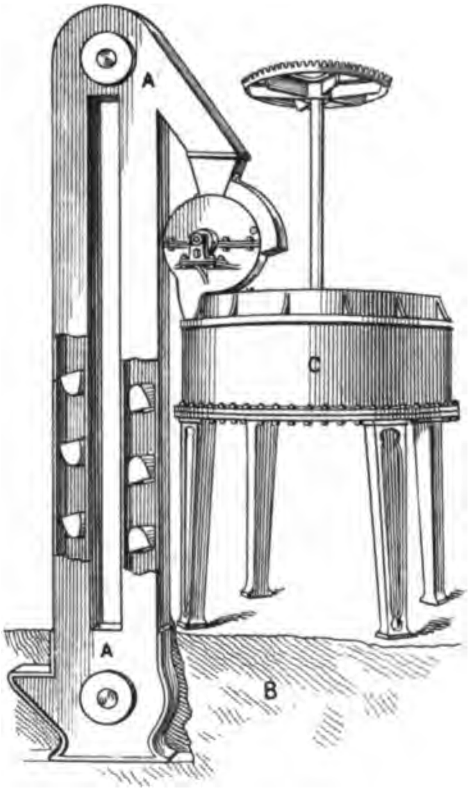


CRUSHING ROLLS.

A, hopper; *B*, rolls: *C*, *D*, driving shafts; *E*, trough for the ground seed.

shoot. Having passed between the two uppermost rolls, the seed is delivered by another curved shoot or guide-plate between the second and third rolls, which crush it further; in similar manner it passes by another guide-plate between the third and fourth rolls, where it receives the final grinding.

FIG. 58.

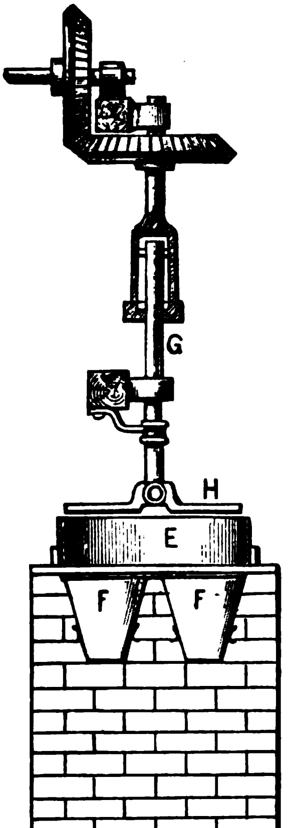


ELEVATOR TO HEATING-PAN.
A, elevator; *B*, trough of crushing-rolls; *C*, heating-pan.

Having passed the last rolls, the ground seed falls into a trough *E*, Fig. 57, or passes through an opening in the foundation into an Archimedean screw and is conveyed to a trough from which an elevator lifts it into a heating-pan as shown in Fig. 58.

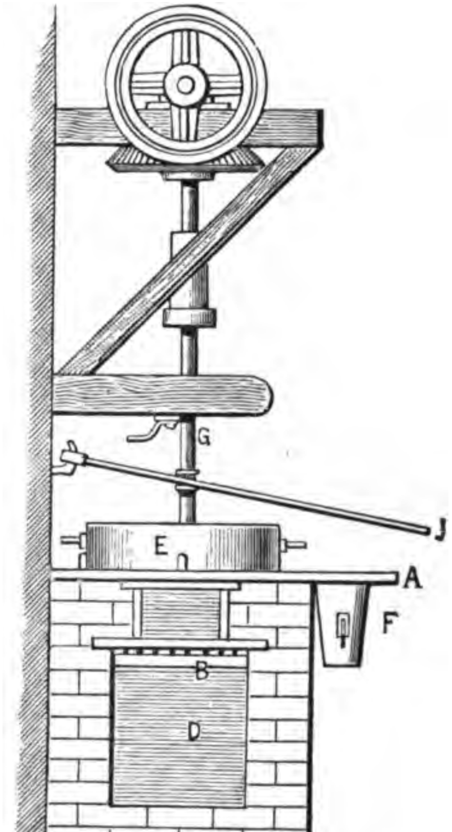
Apparatus for heating the seed meal.—For the preparation of table oils of a pure and mild taste the seed-meal is brought directly into the press and pressed cold; the residue is then heated and subjected to a second pressure. But for oils for domestic and technical purposes, such as lamp and machine oils, the seed is heated before the first pressure.

FIG. 59.



HEATING APPARATUS. FRONT VIEW.

FIG. 60.



HEATING APPARATUS. SIDE VIEW.

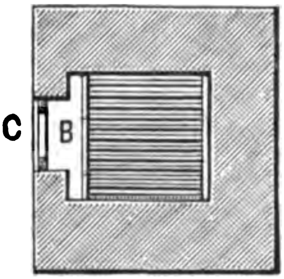
A, cast-iron heating plate; *B*, grate; *C*, stoke hole; *D*, ash pit; *E*, pan with handle; *F*, hopper; *G*, vertical shaft; *H*, stirrer; *J*, lever.

Heating the seed-meal offers many advantages: the oil is rendered more limpid and therefore more easily expressed, a greater yield is obtained, and the albuminous substances are coagulated and the mucus dried up. But, on the other hand, it has the disadvantage that substances of an acrid, disagreeable taste are more readily absorbed by the warm oil, this being the reason why oil for table purposes is cold drawn.

Heating is effected either in shallow pans, or upon plates over an open fire, or by steam. The first method is the oldest, and, though still in use, the practice is by no means judicious.

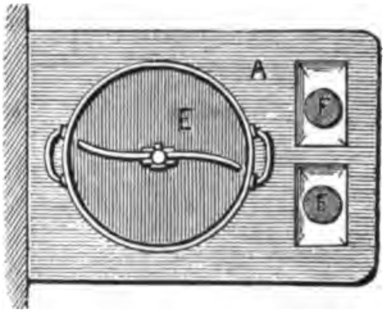
Figs. 59, 60, 61, and 62 show a heating apparatus over an open fire. The cast-iron plate, *A*, sits immediately over the fire-box. The cast-iron or copper pan, *E*, is fastened to *A* by means of screws. The object of the stirrer, *H*, when in motion, is to uniformly mix the meal and to prevent it from being scorched by too long a contact with the hot bottom. To facilitate the emptying of the pan the stirrer, *H*, is raised by the lever, *J*.

FIG. 61.



HEATING APPARATUS.
SECTION THROUGH THE FIRE-BOX.

FIG. 62.



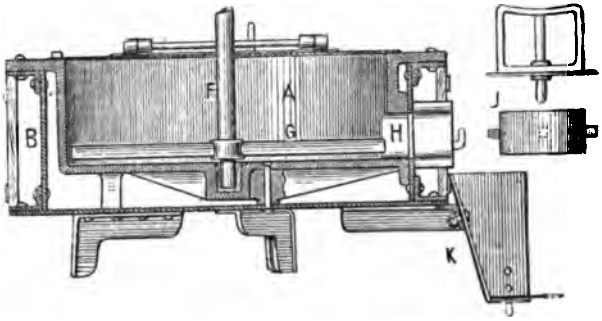
HEAING APPARATUS.
ASH-PAN.

In each pan is only placed at one time the quantity of meal required for one press cake (nine to eleven pounds).

Sufficient heating is recognized by pressing a small sample between the fingers; the oil must thereby run out readily, the mass not become lumpy, but retain the shape received by the pressure.

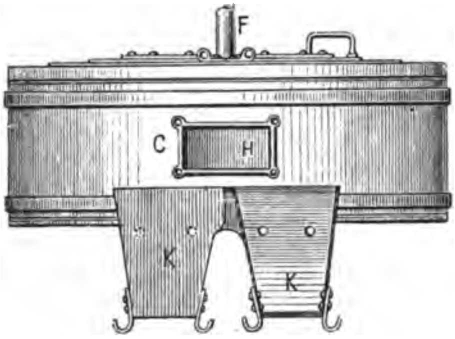
After sufficient heating the movable ring of the pan is removed and the mass poured into bags suspended to hooks on the hopper, *F*.

FIG. 63.



HEATING-PAN. SECTION THROUGH THE CENTRE.

FIG. 64.



HEATING-PAN. FRONT VIEW.

A, cast-iron pan; *B*, sheet-iron jacket; *C*, wooden mantle; *D*, sheet-iron lid with doors *E*; *F*, vertical shaft; *G*, stirrer; *H*, opening; *J*, plug; *K*, hopper.

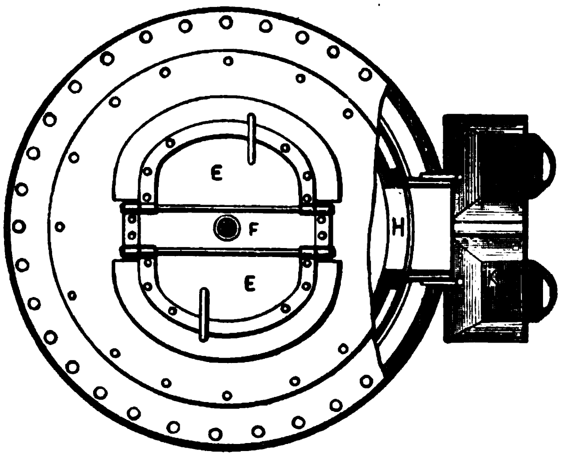
A warming pan according to Rigg, which is fed by low-pressure steam from the principal boiler of a steam engine by means of a low-pressure valve, is illustrated by Figs. 63, 64, 65 and 66.

The vertical section, Fig. 63, shows the interior of the cast-iron pan *A*, surrounded by the sheet-iron jacket *B*, into which steam is introduced. The apparatus is protected from a loss of heat by a covering of felt and the wooden mantle *C*. Fig. 65 shows the ground-plan of the sheet-iron cover *D*, which is provided with two doors through which the meal is introduced.

The vertical shaft *F*, set in motion from the principal shaft by means of bevel wheels, drives the stirrer *G*, which is shown in Fig. 66.

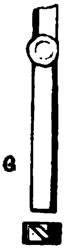
On one side of the cast-iron pan is an opening *H*. This opening can be closed by the plug *J*; on removing the latter the stirrer acts as a shovel and forces the heated meal into the press-bags suspended to the hooks on the two hoppers, *K K*.

Fig. 65.



HEATING PAN. GROUND-PLAN.

Fig. 66.



The bags of strong woollen stuff, when full, are pressed flat between horse-hair mats and then brought into the press.

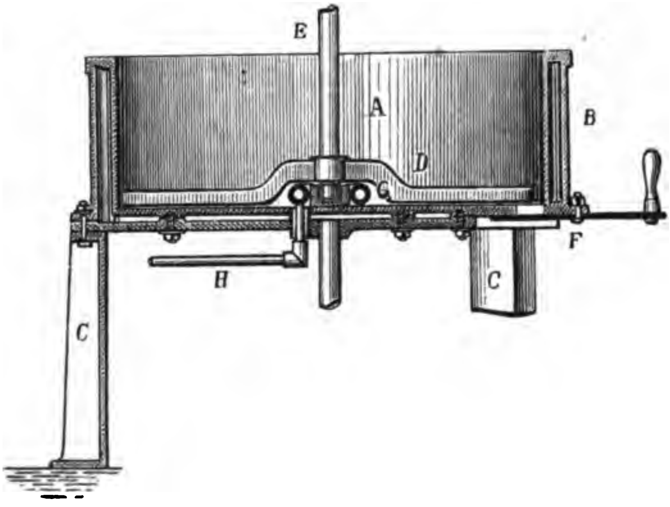
The heating pan rests upon three columns not shown in the illustration.

Another warming pan, in which the seed-meal is saturated with steam, is shown in Figs. 67 and 68.

The novelty of this heating pan is that the seed is not moistened while being ground, but is heated and saturated with steam in the pan.

The inner boiler *A* is surrounded by a second one *B*. In *A* is a circular perforated pipe *C*, through which the steam passes into the seed-meal in *A*. The stirrer *G* is driven from the principal shaft by means of bevel wheels. At *F* is an opening provided with a slide, through which the heated meal is dropped into a vessel holding exactly enough for one press-cake.

FIG. 67.



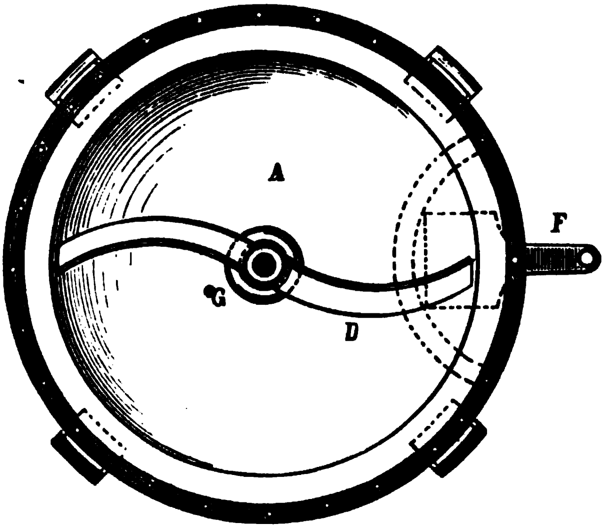
HEATING PAN. SECTION THROUGH THE CENTRE.

_A_, inner boiler; _B_, outer boiler; _C_, supports of the apparatus; _D_, stirrer; _E_, vertical shaft; _F_, opening with slide; _G_, perforated steam-pipe; _H_, pipe for the introduction of steam.

In conclusion, may be mentioned the double warming pan according to Muspratt, the construction of which is shown in vertical section (Fig. 69) and in ground-plan (Fig. 70).

The pan, heated by steam, consists of two cylindrical chambers *A* and *B*, the first being placed over the latter, and both being surrounded by the steam-jacket *C*. Steam is introduced through the pipe *D*, and passes out, together with the water of condensation, through *E*. The shaft *F*, passing through both chambers, is provided with two stirring arms *G*,

FIG. 68.



HEATING PAN. SECTION THROUGH GROUND-PLAN.

and makes thirty-six revolutions per minute, bringing every portion of the meal uniformly in contact with the heated sides and bottom.

The upper chamber *A* is closed with the sheet-iron lid *H*. This chamber is first filled with meal, where it remains for ten to fifteen minutes, and is then brought into the lower chamber by opening the slide *J* on the opening *K*. In the lower chamber the meal remains until it is brought into the press.

The meal, when heated to a temperature of about 176° F., is removed from the pan by the stirring apparatus after opening the slide *K*, and falls into the press-bag suspended to the hopper *M*.

The following explanations of heating apparatus may be added to those already given.

Steam heaters are constructed either of cast iron, or sheet-iron about 2 millimeters thick, and are about 3 feet in diameter and 6 inches high. The stirrer of iron or copper is placed obliquely, and two stirrers of a heater require, with 30 to 36 revolutions per minute, about $\frac{1}{10}$ to $\frac{1}{8}$ horse-power.

FIG. 69.

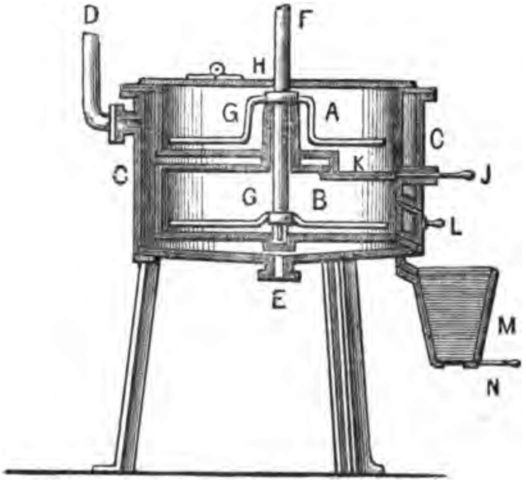
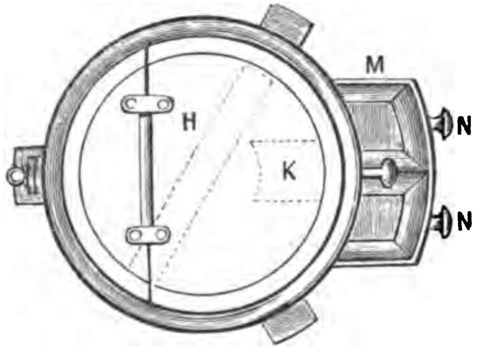


FIG. 70.



DOUBLE HEATING PAN. CROSS SECTION AND GROUND-PLAN.

A and *B*, two cylindrical chambers for the reception of the meal; *C*, steam-jacket; *D*, pipe for introducing steam; *E*, discharge pipe for steam and condensed water; *F*, shaft; *G*, two stirring arms; *H*, sheet-iron cover; *J*, slide; *K*, opening; *L*, door; *M*, hopper; *N*, slide.

For heating either live or exhaust steam is used. The meal is heated to from 167° to 176° F.; the temperature should never exceed that of boiling water. For heating rape-seed for the first pressure with steam of 230° F., about $\frac{1}{2}$ lb. of steam is required, and for the second pressure about $\frac{2}{5}$ lb. For each kilogramme (2.2 lbs.) of meal which is to be tested twice in one hour, a heating surface of 82 square centimeters (12.71 square inches) has to be provided.

Expression of Oil.

After the preparation of the seed by the different machines, it is subjected to pressure. Hydraulic presses are now generally employed, though the old Dutch mill or wedge-press is still occasionally found in small mills. It has the advantage of being cheaper, and by some is held to be better adapted for the expression of oil. The heated seed meal to be subjected to pressure is placed in bags of woolen cloth or horse-hair.

Wedge press.—The wedge press is composed of two principal parts:

1. The press-box, made either of a solid block of oak, with square places cut out for the reception of the meal bags, or of cast-iron.

2. The drivers, consisting of vertical movable wooden rams, which are lifted by a cam-shaft and in falling down act upon the wedges.

Figs. 71 to 86 illustrate the principal view, ground-plan, and separate parts of a wedge press.

The cast-iron or oaken press-boxes *J* rest upon solid brick-work or other firm foundation, in which is also fixed the frame *A* and *B*.

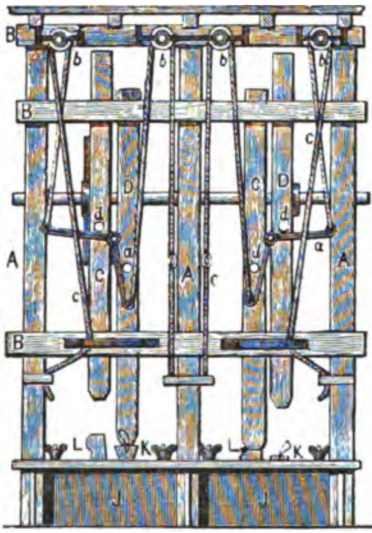
Each press-box contains two press-bags *O*, two corresponding perforated bottoms *M*, and the collecting and discharge pipe *N* for the oil. The press-bags are placed between two movable cast-iron plates *P* and *T*. The lining *Q* and the intermediate pieces or tongues *R* join the plates *T*.

The arrangement of *P* and *T* is plainly shown in Figs. 79 to 86.

On the side of one of the intermediate pieces *R* is the spring wedge *L* suspended by a rope; it serves to take the apparatus to pieces after expression is finished. On the side of the other intermediate piece *R* is the pressing wedge *K*, and between *L* and *K* the intermediate piece *S*. The wedges and intermediate pieces are made of white beech, and the plates *P* and *T* of cast-iron.

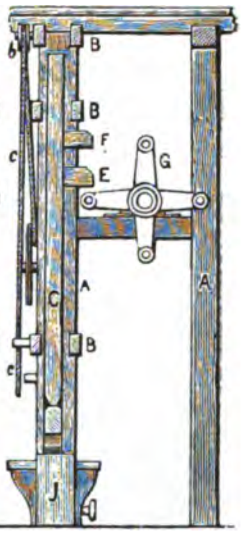
The pressing box is packed in the above-described succession, only the pressing wedge coming last. Care should be had to inclose the meal uniformly in the pressing cloths or bags, so that no creases are formed or layers of meal of unequal thickness, as otherwise the press-plates run crooked and the press-cloths and the press itself suffer injury.

FIG. 71.



WEDGE PRESS. FRONT VIEW.

FIG. 72.

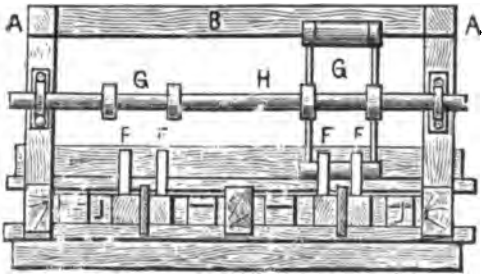


WEDGE PRESS. SIDE VIEW.

The front view, side view, and ground-plan of the wedge press are shown in Figs. 71, 72, and 73. *A* are the uprights of the framework, *B* horizontal supports which serve for vertically guiding the rams *C* and *D*, provided with the lifts *E* and *F*. Under the lifts catch the wipers *G*, which sit upon the shaft *H*.

The rams *C* and *D* are vertically placed over the press-box, so that the ram *C* strikes the spring wedge *L*, and *D* the pressing wedge *K*. The rams work alternately, so that while *C C* are at work *D D* stand still, and *vice versa*.

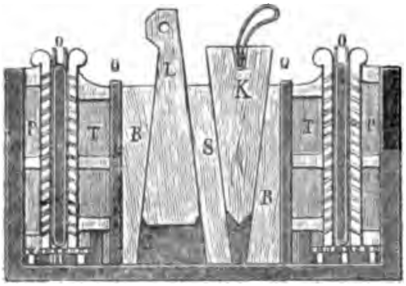
FIG. 73.



WEDGE PRESS. GROUND-PLAN.

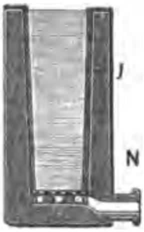
The rams are stopped by the joint lever *a* by means of the cord *c* running over the pulleys *b*. The cord catches under the peg *d* and raises the rams sufficiently, so that the lifts *E* and *F* are no longer reached by the wipers *G* upon the shaft *H*.

FIG. 74.



PRESS-BOX.
LONGITUDINAL SECTION WITH PRESS-BAGS.

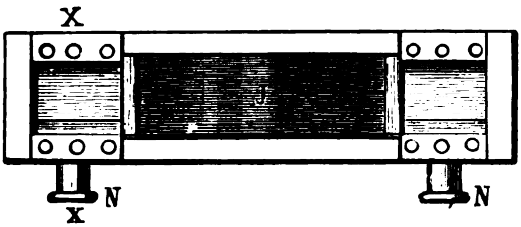
FIG. 75.



PRESS-BOX.
CROSS SECTION WITHOUT PRESS-BAGS, IN LINE OF *X X*.

Everything being arranged in proper order, the rams *D* are set in motion, whereby the press wedge *K* is forced deeper and deeper between the other parts, exerting a pressure of gradually increasing force upon the press plates. The oil running through the perforations of the plate and the pipe *N* is caught up by a vessel. After the exhaustion of the meal the ram *D* is stopped and a few strokes given to the spring wedge *L* by the ram *C*. This forces the spring wedge into the empty spaces, thereby loosening the other wedges.

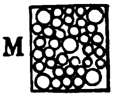
FIG. 76.



PRESS-BOX. GROUND-PLAN WITHOUT PRESS-BAGS.

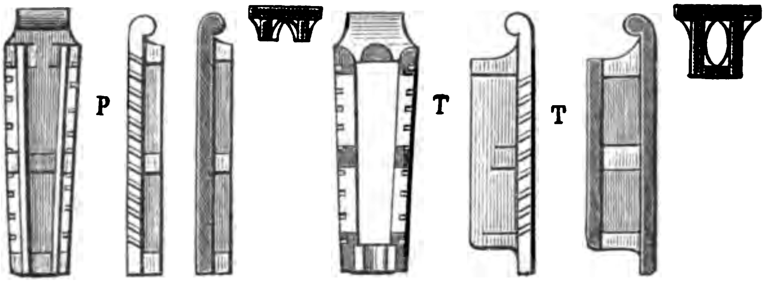
FIG. 77.

FIG. 78.



SECTION AND GROUND-PLAN OF THE PERFORATED BOTTOM.

FIGS. 79, 80, 81, 82, 83, 84, 85, 86.



FIGS. 79, 80, 81, 82, VIEWS AND SECTIONS OF THE PLATE *P*.
FIGS. 83, 84, 85, 86, VIEWS AND SECTIONS OF THE PLATE *T*.

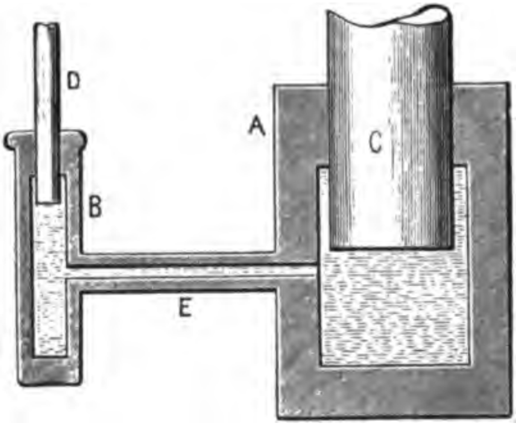
Great precaution is required in stopping the rams and loosening the wedges.

In proportion to the time and labor required, the wedge-press allows of but light charges; the useful effect is equal to ¾ of the absolute work. The rams are about 16 feet long with a square diameter of 8 to 8¼ inches. The longest stroke is about 23 inches. Fifteen strokes may be given per minute, which, with a press-cake of 10 or 11 lbs., forces the wedge down in about 6 minutes. A wedge-press furnishes about 13 cwt. oil-cake per day.

For the first pressure only 10 to 12 strokes are used, while for the second pressure 36 to 40 strokes are required.

Hydraulic presses.—The hydraulic press is based upon the law of hydrodynamics, first clearly stated by Pascal, that liquids transmit equally in all directions a pressure exerted at any point of their mass. If, therefore, the cylinders *A* and *B*, Fig. 87, are completely filled with a liquid, and a pressure is exerted by the piston *D* being pushed with a certain force into the liquid, this pressure will be transmitted, and the walls of the cylinders and those of the connecting pipe *E*, as well as the lower surface of the piston *C*, will stand under the same pressure. The piston *C*, being movable, is pushed upwards with a force as many

FIG. 87.



A, large cylinder; *B*, small cylinder; *C*, large piston; *D*, small piston; *E*, connecting pipe.

times greater than the pressure exerted by *D* as its surface is greater than *D*.

Now suppose the area of the piston *C* to be twenty times as laage as that of the piston *D*. Hence it follows that if we press in the piston *D* with a force of ten pounds, the piston *C* will be forced out with twenty times as much force, or two hundred pounds; and, on the other hand, if we press in the piston *C* with a force of two hundred pounds, the piston *D* will be forced out with a force of only ten pounds. It is evidently unimportant that the connection should be so direct as in Fig. 87. If it is effected by a long and narrow tube the principle will still hold true, provided only that the joints are tight and the material of the vessel unyielding.

The hydraulic press in general use is only a modification of the apparatus represented by the diagram Fig. 87, the pressure with the piston *D* being not exerted by simply pressing it into the liquid, but by moving it up and down.

In descending the piston *D* presses upon the liquid, while in ascending it sucks fresh liquid from a reservoir, both periods being separated from each other, so that during the ascent the water in the press cylinder is shut off from the pump, thus preserving the pressure in the cylinder.

Fig. 88 shows the press cylinder *A* with its piston *C*, which carries a press plate or platform *F*. The articles to be pressed are placed between this and a second platform or press head *G*, which is connected with the press cylinder by the columns *H*.

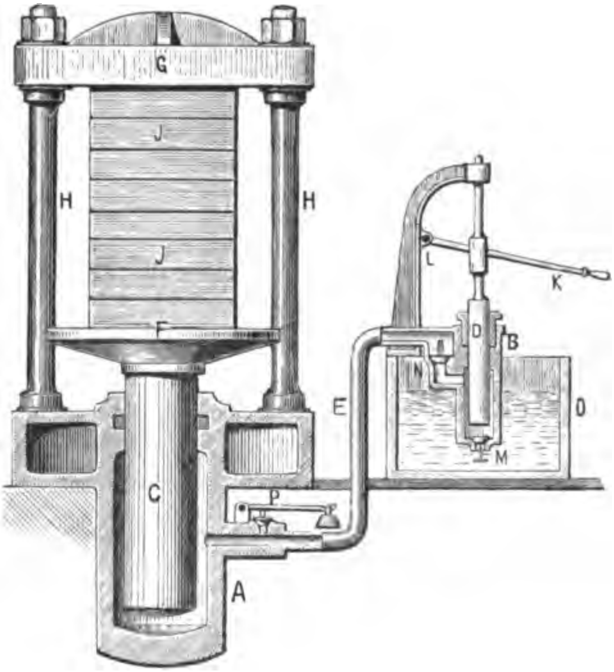
The press is put in motion by moving the piston *D* up and down by means of the lever *K*, the fulcrum of which is at *L*.

On the lower end of the pump cylinder *B*, which holds the piston *D*, is the suction valve *M*, and in the delivery pipe *E* the delivery valve *N*.

The pump cylinder is connected with a reservoir of liquid, so that on raising the piston *D*, fluid from the reservoir *O* can enter the cylinder *B* through the valve *M*, which opens, while the delivery valve *N* remains closed.

Now by pressing the piston *D* down, the suction valve *M* is closed, and the liquid displaced by the piston escapes through the opening delivery valve *N* in the delivery pipe *E* into the cylinder *A*. The piston *C*, with the press plate *F*, ascends, and by approaching the stationary press head *G*, compresses the material placed between *F* and *G*.

FIG. 88.



ARRANGEMENT OF THE HYDRAULIC PRESS AND PUMP-WORK.

A, press cylinder; *B*, pump cylinder; *C*, press piston: *D*, pump piston; *E*, delivery pipe; *F*, press plate; *G*, press head; *H*, connecting columns; *J*, press material; *K*, lever; *L*, fulcrum of lever; *M*, suction valve; *N*, delivery valve; *O*, reservoir; *P*, safety valve.

During the ascent of the piston *D*, the delivery valve *N* closes again, and as the material undergoing pressure always exerts a certain elastic resistance, the liquid in the press cylinder remains under the same pressure.

The delivery pipe *E* is further provided with a safety-valve

P, kept in place by a weight acting on it through a lever. As soon as the pressure exceeds a determined maximum the valve opens and the pressure is relieved by the escape of water.

Further observations will be made in discussing the details of presses and pumps.

Hydraulic presses used in the extraction of oil do not essentially differ from those for other purposes, and now introduced in all large oil mills. They are either of a vertical or horizontal construction, the latter form offering greater convenience for catching the oil. In many mills both systems are found, the vertical press being used for the first pressure and the horizontal one for the second, or *vice versa*.

Box press.—This, the simplest form of a vertical press, is illustrated by Figs. 89, 90, and 91. The cylinder *A* is connected with the head *D* by three wrought-iron rods *E*. The press-plate *C* is provided with a channel from which the oil runs off through a pipe.

The sieve-like press-box *F*, Figs. 89 and 91, is strengthened by wrought-iron rings; between the rings are five rows of conical holes. There is, further, a sheet-iron jacket *G* to prevent the oil from squirting.

The press-plate *C* allows the press-box *F* to be shifted so that the filled press-bags and the plates can be conveniently placed in position. The plate is also provided with a circular opening larger in dimensions than the press cake, to facilitate the emptying and removal of the latter.

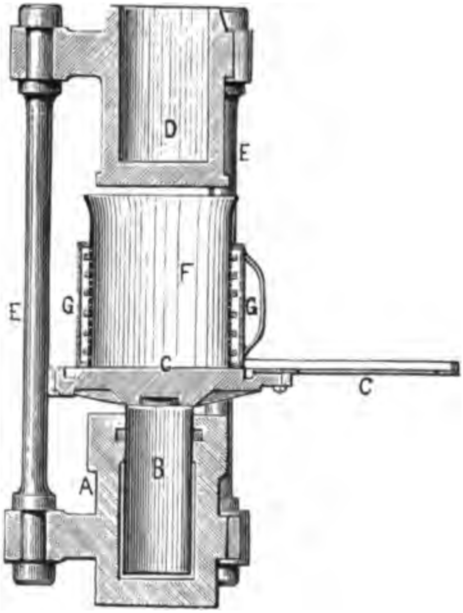
The seed-meal is packed in bags of sheep's wool, a circular iron plate without holes and about one-quarter inch thick being placed between every two bags.

The press-box holds 5 or 6 bags, each weighing about 22 pounds, so that 110 to 132 pounds of seed-meal are pressed at one time.

The pressure upon the bags, which amounts to about 150 atmospheres, reduces their bulk from about 20 inches in thickness to about 8 or 9 inches.

As this press is exclusively used for the first pressure, the round form of the cake is chosen.

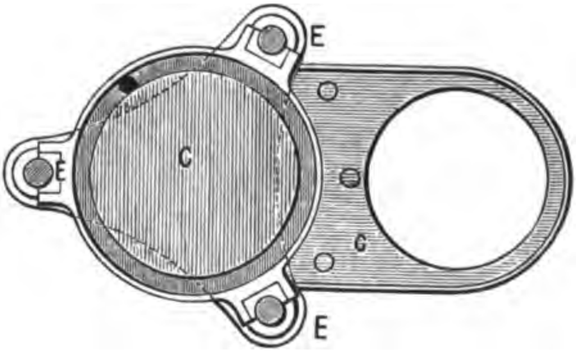
FIG. 89.



HYDRAULIC PRESS. SECTION THROUGH THE CENTRE.

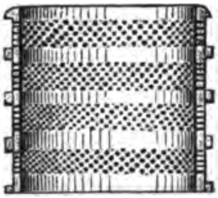
A, press-cylinder; *B*, ram; *C*, press-table; *D*, head; *E*, drawing rods; *F*, press-box; *G*, sheet-iron jacket with handle.

FIG. 90.



GROUND-PLAN OF THE PRESS-TABLE.

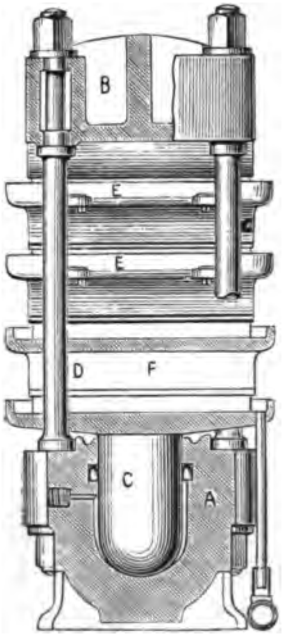
FIG. 91.



SIEVE-LIKE PRESS-BOX.

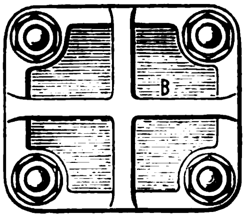
Experience has shown it to be better to press the cakes in separate boxes than in one.

FIG. 92.



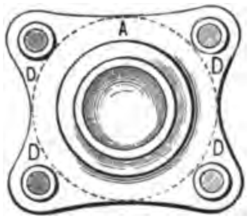
HYDRAULIC PRRSS.

FIG. 93.



PRESS-HEAD.

FIG. 94.



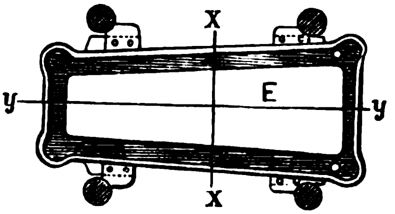
PRESS-CYLINDER.

A, press-cylinder; *B*, press-head; *C*, ram; *D*, vertical rods; *E*, press-boxes; *F*, collecting pipe.

Figs. 92 to 98 illustrate a modern press with four boxes, which are shown in views and sections in Figs 95, 96, 97, and

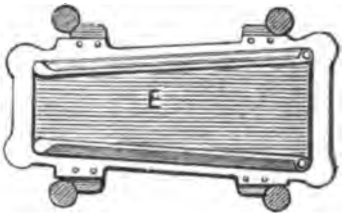
98. The boxes *E* slide between the vertical rods *D* of the press, and are pressed together after having received the press material and the horse-hair mats. The oil runs into gutters and from there into a reservoir. After the oil is expressed, the press water is discharged through a valve, the piston and boxes fall down by their own weight, the horse-hair mats are taken out and the press cake is removed from the bag. The edges of the press cake, which still contain oil, are cut off, ground under runners, and again subjected to pressure.

FIG. 95.



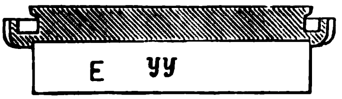
PRESS-BOX. VIEW FROM ABOVE.

FIG. 96.



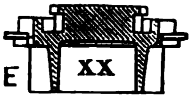
PRESS-BOX. VIEW FROM BELOW.

FIG. 97.



SECTION: *y* TO *y*.

FIG. 98.



SECTION: *x* TO *x*.

The hydraulic press, described above, has a ram with a diameter of nearly 10 inches, and works with a pressure of about 660 pounds per 0.155 square inch.

Figs. 99 to 102 show a hydraulic press according to Rose, Downs, and Thompson, in which the seed-meal, enveloped in woolen cloths, is placed between press plates and pressed.

The press is shown in a charged state. The press cylinder has a diameter of about 13 inches, and the pressure is equal to about 265 pounds per 0.155 square inch.

The crushing rolls, also patented in England by Messrs. Rose, Downs, and Thompson, used in connection with these presses, differ from the ordinary ones in the number and arrangement of the rolls. Four of them are used, and are arranged vertically above each other. The rolls are also much longer, being about 3¼ feet long, while those formerly used were at the utmost about 1.64 feet long.

FIG. 99.

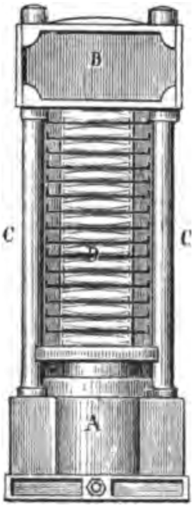


FIG. 100.

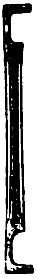


FIG. 101.

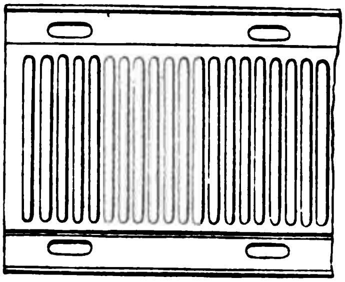
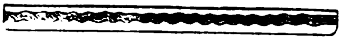


FIG. 102.



HYDRAULIC PRESS. PRESS PLATES. LONGITUDINAL AND CROSS SECTION.

A, press-cylinder; *B*, head; *C*, vertical rods; *D*, press-plates.

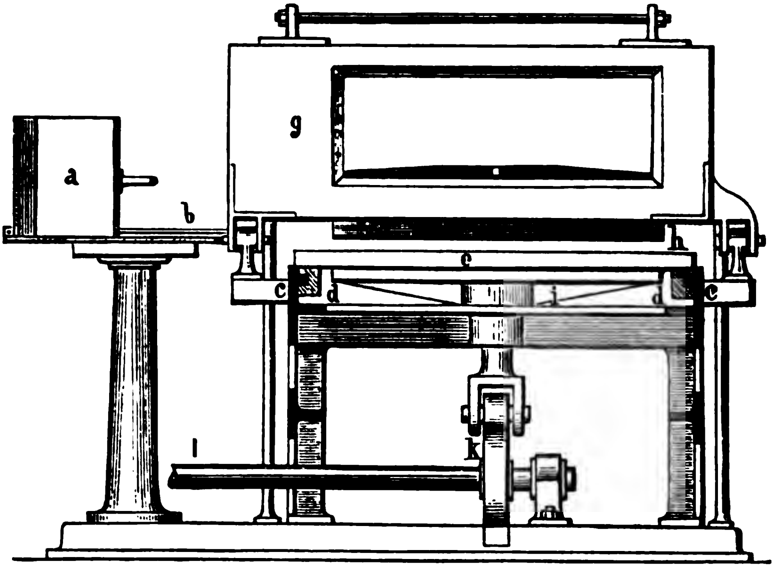
The brasses of the rolls can be vertically shifted in the frame, the seed passing through between all the rolls.

After the seed has been brought between the first and second rolls it is removed from the first roll by a stationary scraper, falls between the second and third rolls, and finally between the latter and the fourth.

By the use of these crushing rolls the work of grinding the seed between millstones is done away with and the crushed seed is immediately lifted into the heating pan, shown in Figs. 67 and 68, pages 255 and 256. From the heating pan it is brought into a vessel the volume content of which corresponds exactly to the quantity required for each press-cake.

By means of these vessels the crushed seed is conveyed to a forming or pressing machine (Figs. 103, 104, and 105) by which the seed is shaped into a form suitable for the press, thus making a considerable saving in the working expenses.

FIG. 103.



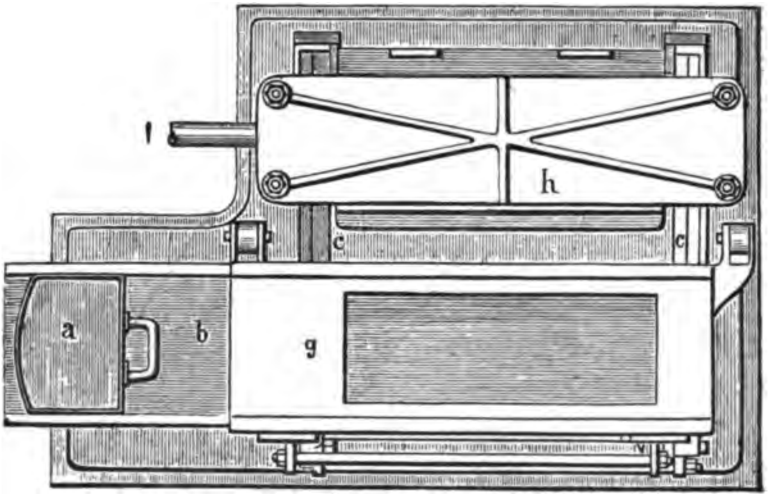
FORMING MACHINE. FRONT VIEW.

The measuring vessel *a*, Fig. 103 and 104, is filled from the heating pan and then pushed to the right upon the plane *b*.

The machine has two slides *c c*, in which two slide bars *d d* are shiftable; upon the latter is placed a vessel *e* of light steel sheet with a wooden frame. In this vessel is placed the cloth *f*, so that it hangs down on both sides.

Upon the vessel *e* and the cloth *f* is placed the wooden frame *g*, movable in a hinge. On top of *g* is a guide for the measuring vessel *a*, which moves upon the plane *b* towards the frame *g*, and in passing over it empties the seed upon the cloth *f*. This operation is especially illustrated by Fig. 106. The frame *g* is then turned up, and after folding the cloth over the seed, the slide bars *d d*, with the vessel *e* resting upon them,

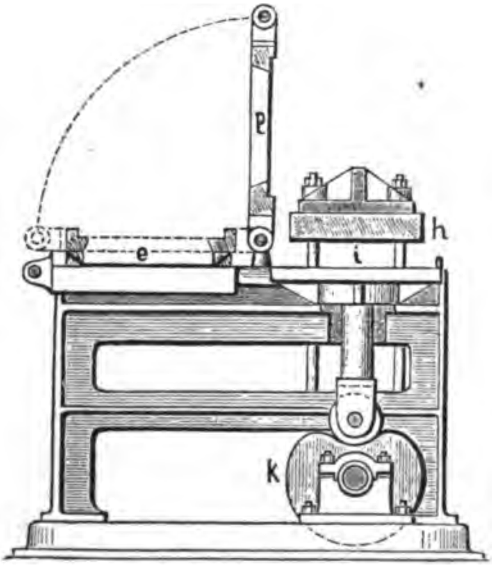
FIG. 104.



FORMING MACHINE. GROUND-PLAN.

a, measuring vessel; *b*, plane; *c*, slide; *d*, slide-rod; *e*, vessel; *f*, cloth; *g*, frame; *h*, press head; *i*, press plate; *k*, wiper; *l*, shaft.

FIG. 105.

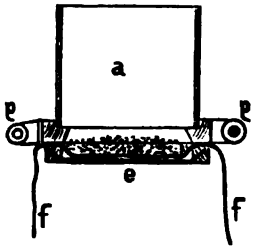


FORMING MACHINE. SIDE VIEW.

are pushed under the press head *h*, so that the vessel *e* stands upon the press plate *i*, as shown in Fig. 104.

By the wiper *k*, set in motion by the shaft *l*, which makes four revolutions per minute, the press-plate *i*, with the vessel *e*, is pressed upwards against the stationary press-head *h*, and the seed enveloped in the cloth *f* subjected to a preliminary pressure.

FIG. 106.



MANNER OF FILLING FORM.

By an arrangement not shown in the illustrations, every time the vessel *e* is pushed under the press-head *h*, the cam-shaft *l* is automatically engaged. It is connected by a coupling with a shaft constantly revolved from the principal shaft.

The coupling is automatically engaged, and, as soon as the wiper has made one revolution, is again automatically disengaged. After removing the vessel *e*, the cake is brought into the press.

During the time of pressure, which lasts about ¼ minute, a second vessel is filled in the described manner, and so on.

The advantages of this machine are as follows:

1. The expensive hairs are done away with.

2. Each press, instead of four cakes, as formerly, can now receive eighteen with the same height between the head and ram, on account of the slight thickness of the cakes themselves, which has been reduced from about 3¼ inches to 1¼, and the absence of the thick hairs.

The cakes are then placed between the press plates in the press, and pressed.

The oil collects in a reservoir from which it is conveyed, by means of pumps, to the general reservoir large enough to hold 2000 tons of oil.

The cakes coming from the press are taken from the cloths and the edges trimmed off with a cutting machine. These edges are then ground fine under runners, and the resulting meal mixed uniformly with fresh material previously to being brought into the heating pan.

FIG. 107.

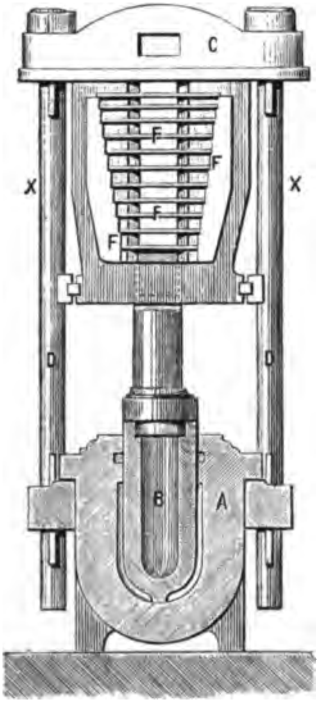
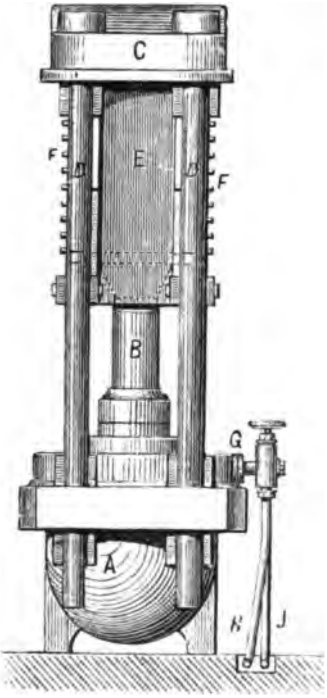


FIG. 108.



HYDRAULIC PRESS.

Front view. *Side view.*

A, press-cylinder; *B*, ram; *C*, head; *D*, drawing rods; *E*, press-room or cake-chamber; *F*, press-plates; *G*, joint pipe; *H*, delivery pipe; *J*, discharge pipe.

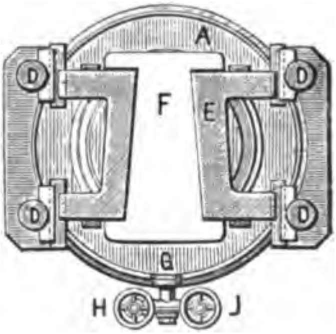
This manner of treatment is based upon the experience that the interior of the cake contains but little oil, it being forced in pressing to the edges.

The advantages claimed for this system are as follows:

1. A saving of 20 per cent. in working expenses.
2. Great saving of space.
3. Better appearance and better quality of the cakes.
4. A greater exhaustion of the seed, the cakes retaining, by the old process, 10½ per cent. of oil, and by this system only 7 per cent.
5. Saving of about 50 per cent. of working power.

Another form of hydraulic press is shown in Figs. 107, 108, and 109.

FIG. 109.



SECTION.

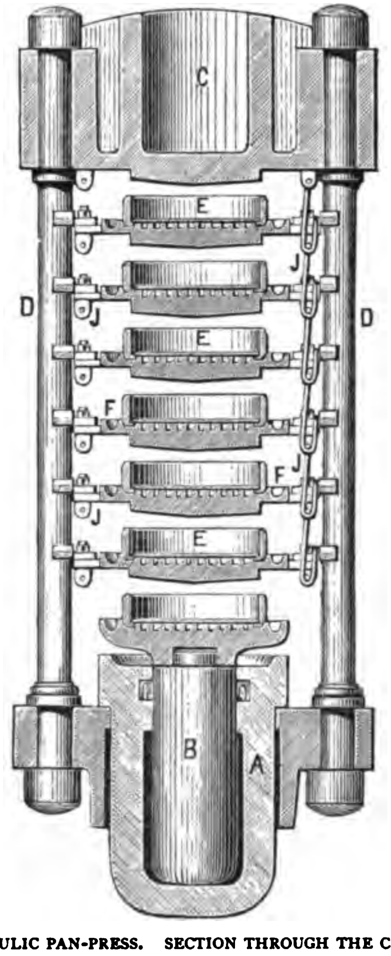
The meal packed in cloths is placed between the separate plates *F*, which rest with their projecting edges upon the lateral step-like metal plates.

The ram *B* catches first the lower plate *F*, and in the course of the pressing operation lifts all the plates from their seats and presses the cakes packed between them.

On the side of the press-cylinder *A*, Fig. 109, is the joint pipe *G* for the press water; it is also used for discharging the press water after the operation, so that the ram descends by its own weight.

From the joint pipe *G* branch off two pipes, one leading to the pump, and the other to the discharge place; both can be closed by a stop-valve.

FIG. 110.

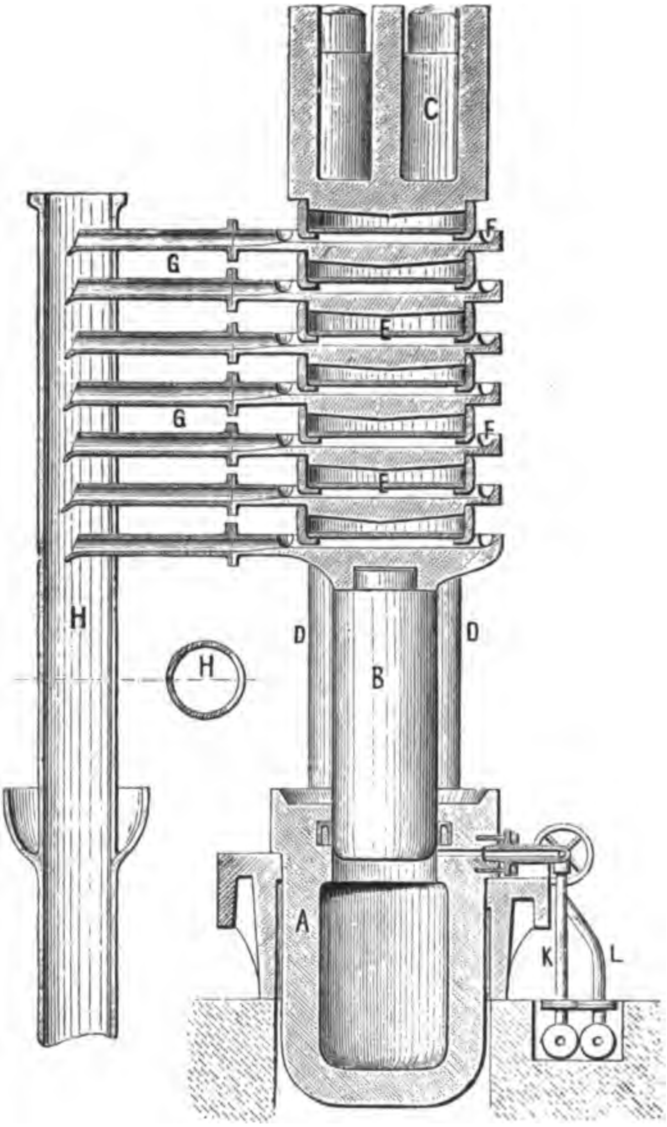


HYDRAULIC PAN-PRESS. SECTION THROUGH THE CENTRE.

A, press-cylinder; *B*, ram; *C*, head; *D*, drawing rods; *E*, press-pans; *F*, collecting gutters; *G*, discharge pipes for oil; *H*, collecting pipe; *J*, hooks; *K*, delivery pipe; *L*, discharge pipe for water.

There are 11 press plates; the cakes are trapeziform, about 19 inches long, and 9¾ and 7 inches wide, and are placed be-

FIG. 111.



HYDRAULIC PAN-PRESS. SECTION THROUGH THE DISCHARGE PIPES.

tween the 11 plates at distances of about 2¼ inches in the clear.

The greatest pressure exerted upon the cakes is 440 pounds per 0.155 square inch.

The entire operation consumes fifteen minutes, six of which are required for filling and emptying.

The greatest pressure in the cylinder is 280 atmospheres; this pressure, with a ram diameter of twelve inches, being equal to 454,000 pounds.

Pan presses.—A press with separate round press-pans is illustrated by Figs. 110 and 111.

The bottom of the pan *E* is covered with a perforated sheet-iron plate, beneath which gutters lead to a concentric collecting gutter *F*, from which the discharge pipe *G* leads to the collecting pipe *H*.

The pans are so shaped that the lower massive part of one pan fits into the cavity of the one below.

Before pressing, the pans *E* are suspended to the head by means of the hooks *J*. They are conveyed through between the four drawing rods *D*, being lifted from the hooks, to which they return after the operation is finished and the discharge of the press water.

The delivery pipe *K* and the discharge pipe *L* are jointed to the press-cylinder, each pipe being provided with a stop-valve.

There are seven pans, each 0.31 inches deep. The meal is pressed together to $\frac{4}{10}$ of its original volume, with a pressure of 330 pounds per 0.155 square inch, while the greatest water pressure in the cylinder is equal to 250 atmospheres.

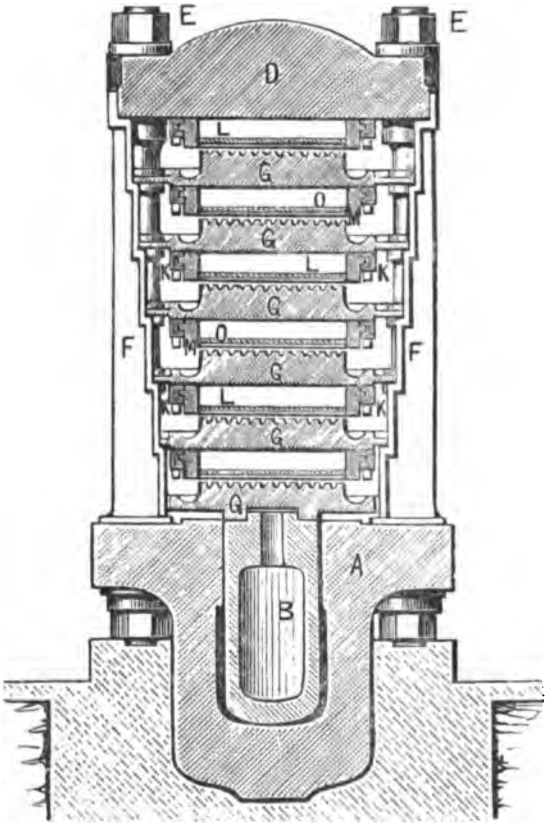
Inclusive of five minutes for charging and emptying the pans, the operation is finished in fifteen minutes.

Ehrhardt's patent press.—A similar principle of one pan being always a guide for the next one is made use of by M. Ehrhardt in his patent press, Figs. 112, 113, 114 and 115.

This press is constructed in accordance with the knowledge derived from experience, that the method of pressing all the cakes in one box is less advantageous than pressing each cake by itself in a special pan.

The pans are movable laterally, so that while one set is subjected to pressure, another set is filled and inserted after removal of the first by pushing it aside.

FIG. 112.



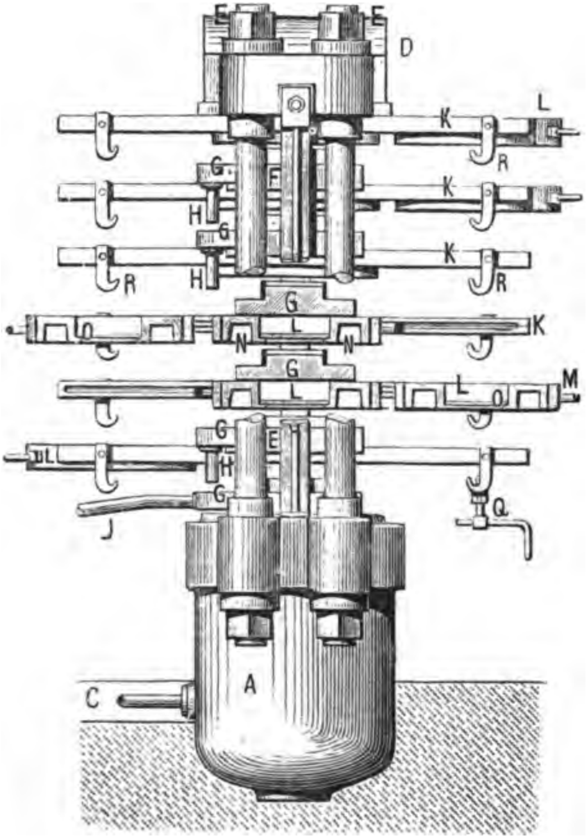
EHRHARDT'S PATENT PRESS. SECTION THROUGH THE PRESS.

A, cylinder; *B*, ram; *C*, water-pipe; *D*, head; *E*, connecting rods; *F*, standards; *G*, press-stamp; *J H*, discharge pipes for oil; *K*, slide bars; *L*, press-pans; *M*, ring of the press pans; *N*, segments; *O*, strainer; *P*, strap; *Q*, screw for emptying arrangement; *R*, hooks.

The press consists of the cylinder *A* with the ram *B* and the water-pipe *C*. The head *D* is connected with the cylinder by four wrought-iron rods *E*.

Two cast-iron standards support, upon equidistant projections, the press-stamps *G*, which have grooved surfaces and a gutter in which the oil collects. The oil runs through the small pipes *H* to the lowest stamp *G*, from which it is conveyed through the pipe *J* into vessels.

FIG. 113.



EHRHARDT'S PATENT PRESS. VIEW AND SECTION.

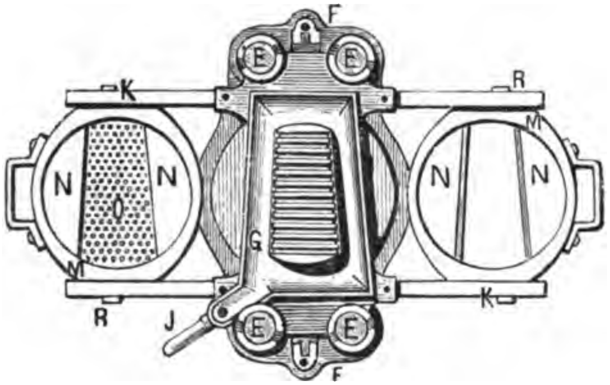
The stamps are guided by the rods *E*.

The lower part of each stamp *G* is provided with two slide bars *K* for the guidance of the two press-pans *L* belonging to the stamp next below. Each press-pans consists of a wrought-iron ring *M* with two segments *N* fastened to it. The free inner side of these segments forms the longitudinal inner side of the actual press-pan *L* containing the seed-meal. Below, the segment is provided with a nose-like projection upon which rests loosely the strainer *O* of the pan *L*.

When the press ascends, each stamp, by being lifted from its support, forces the strainer immediately above it upwards, thereby effecting the expression of the seed, which is placed directly in the pan without the intervention of mats.

As previously stated, two pans belong to each stamp. As soon as the pressing is finished the pan under the press is pushed outward and the one on the opposite side, which has in the meanwhile been charged, inserted.

FIG. 114.



EHRHARDT'S PATENT PRESS. GROUND-PLAN.

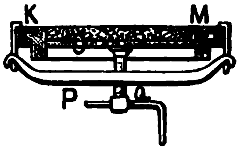
The press cake is removed from the pan by the broad head of the screw *Q*, movable in the strap *P*. The latter is supported by two hooks *R* fastened to the slide bars, so that it can readily be placed in position.

The preparatory presses with 4 plates and 8 pans, with an ordinary pump with a pressure of 250 atmospheres, admit of 8 expressions per hour, and with accumulators, of ten.

By the second pressure with 6 plates and 12 pans, 48 to 60 cakes are produced per hour.

This second pressure has the great advantage that the cakes leave the press completely finished, *i. e.*, with sharp edges, and do not require trimming, as is necessary with all other presses where the meal is placed in bags or cloths.

FIG. 115.

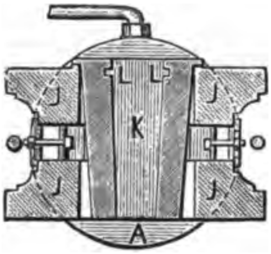


EMPTYING THE PAN.

Horizontal presses.— Horizontal hydraulic presses must be provided with a special arrangement to reconduct the ram, which, in vertical presses, returns by its own weight after the discharge of the press water.

The return of the ram can be effected by counter-weights, but is better accomplished by a second small press—the so-called counter-press. This arrangement is illustrated by Figs. 116, 117 and 118.

FIG. 116.

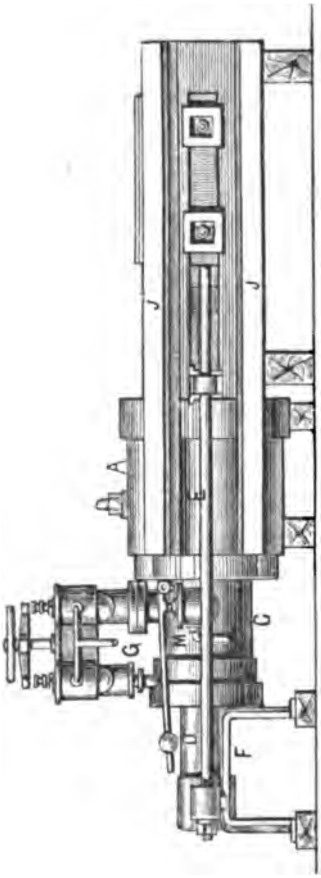


HORIZONTAL HYDRAULIC PRESS WITH COUNTER PRESS.
SECTION THROUGH THE PRESS ROOM.

To return the ram *B* after pressure to the lowest stroke, the counter press, which is guided straight by two wrought-iron stays *F*, is connected with the ram by the drawing rods *E*.

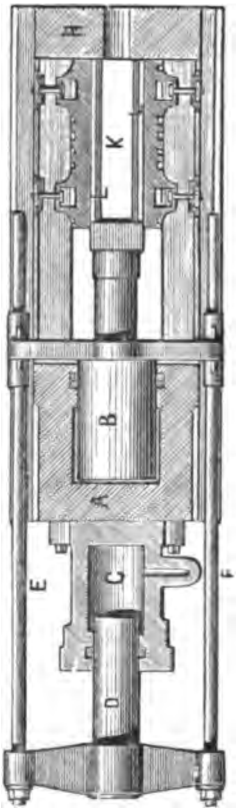
By means of a double stop-cock the water required for pressure can be conducted into the counter press or into the regular press.

FIG. 117.



HORIZONTAL HYDRAULIC PRESS. LONGITUDINAL VIEW.

FIG. 118.



HORIZONTAL HYDRAULIC PRESS. SECTION THROUGH THR CYLINDER.

A, cylinder of the press; *B*, ram of the press; *C*, cylinder of counter press; *D*, ram of same; *E*, drawing rods; *F*, stays; *G*, stop-valve; *H*, head; *J*, connecting beams; *K*, cake chamber; *L*, groove in cake chamber; *M*, safety-valve.

The head *H* is not, as in vertical presses, connected with the cylinder by rods, but by cast-iron beams *J*, the upper surfaces of which form the working table, while the lower rest upon the foundation.

These beams *J*, the cylinder *A*, and the head *H*, are cast in one piece. In the head is a hole for the introduction of the drill in boring out the cylinder, which is afterwards filled up by an iron plug. The piston is guided in the groove *L* in the cake chamber *K*. The latter hangs by projecting ledges to the upper surface of the beam *J*; brackets screwed to *J* catching on each side into the interspace.

Now the ram *B* is connected with the ram *D* by the drawing rods *E*. If, therefore, after completed pressure, the water is conducted into the counter press, the ram *D* draws back the ram *B* by means of the drawing rods *E*.

FIG. 119.

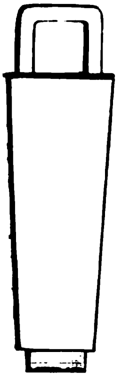
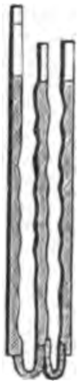


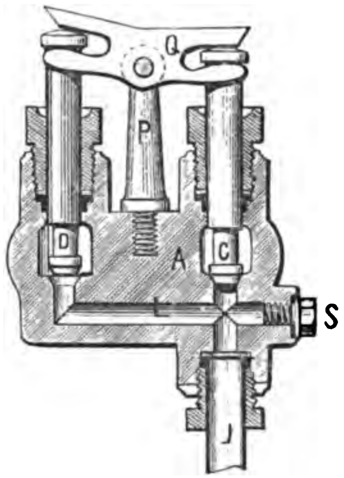
FIG. 120.



PRESS-PLATE.

Profile. *Section.*

FIG. 121.



VALVE. SECTION THROUGH VALVES *D*—*C*.

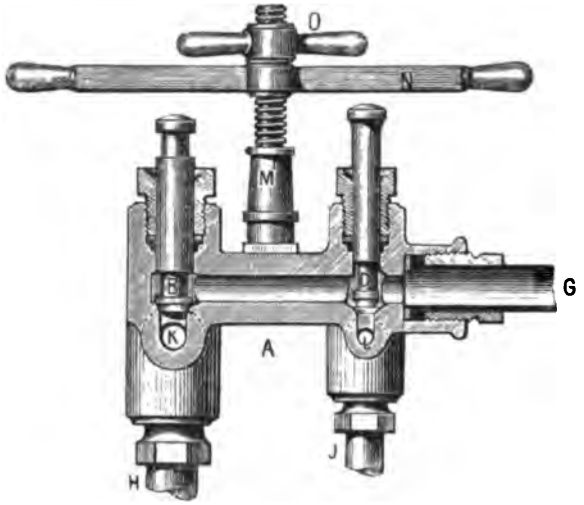
Figs. 119 and 120 show the press plates in profile and section; each series of three plates being connected by leather couplings.

In order to properly conduct the water from the injecting pump alternately into the cylinder of the oil-press and into the counter-press, an arrangement, as shown in Figs. 121, 122, and 123, is required.

A valve box with four valves is placed in the horizontal press or in the pump box.

Four pipes enter the valve box; *F* is the pressure pipe which conducts the water from the injecting pipe, and *G* the discharge pipe for water used. The pipe *H* leads to the oil press, and the pipe *J* to the counter press.

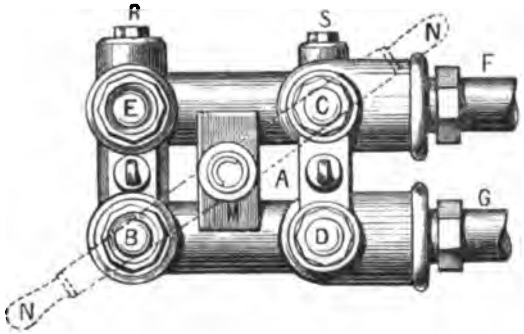
FIG. 122.



SECTION THROUGH VALVES *B—D*.

A, valve box; *B*, *C*, *D*, *E*, valves; *F*, press pipe; *G*, discharge pipe; *H*, conduit to oil press; *J*, conduit to counter press; *K*, *L*, bores in the valve box *A*; *M*, column with screw; *N*, hand lever; *O*, handle; *P*, columns; *Q*, lever; *R*, *S*, shoulders.

FIG. 123.



VALVE. GROUND-PLAN.

The pipes *F* and *G* communicate by the bores *K* and *L*. The opening and closing of the valves are effected above the cross by the column *M* provided with a screw, which stands in the centre of the valve box. The hand lever *N* can be loosely turned around the screw, and also pushed up and down, the thread of the screw being besides provided with the handle *O*.

Between the valves are two other columns *P*, which, by catching the valve rods, can raise them up or press them down.

In the illustration the hand lever *N* is so placed that it presses down the lever *Q* on each end, whereby the valves *B* and *C* are closed and the valves *D* and *E* opened.

The hand lever *N* is pressed down by screwing down the handle *O*.

In this position the water coming from the pump runs through *F* over the closed valve *C*, and through the open valve *E*, and through the pipe *H* into the cylinder of the press.

At the same time the water escapes from the counter press through the pipe *J*, passes through the open valve *D*, and runs off through the discharge pipe *G*.

To draw back the ram of the press after completed pressure by means of the counter press, the handle *O* is loosened and the lever *N* placed upon the other two levers and pressed upon them by screwing down the handle *O*, whereby the valves *D* and *E* are closed and the valves *B* and *C* opened.

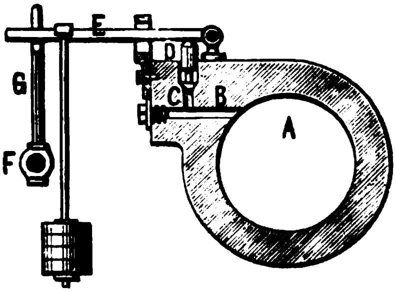
The water passes now directly from the pump through the pipe *J* and the open valve *C* into the counter press, while the water from the oil press flows back through the pipe *H* and the open valve *B* to the discharge pipe *G*.

Now, suppose, by a mistake, the position of the valve were incorrect, and the stroke of the counter press not limited, there would be danger of the breaking of the connecting rods of the cam and of those of the press.

To prevent this a safety-valve, Fig. 124, is provided. It is placed in a shoulder of the cylinder of the counter press. In the shoulder is a bore hole *B*, with another bore hole *C* vertical to *B*. *B* is closed as far *C* by a screw, while the valve *D* is placed in the bore hole *C*.

The valve *D* is pressed upon its seat by the weighted lever *E*. A bent arm is connected with one of the connecting rods. By a progressive movement of *F* the bent part of *G* lifts the lever *E* by being pushed against it, whereby the valve is raised by the water pressure prevailing in the cylinder *A*, so that the press water is discharged before the ram of the counter press has reached the end of its stroke.

FIG. 124.



SECTION THROUGH THE SAFETY-VALVE.

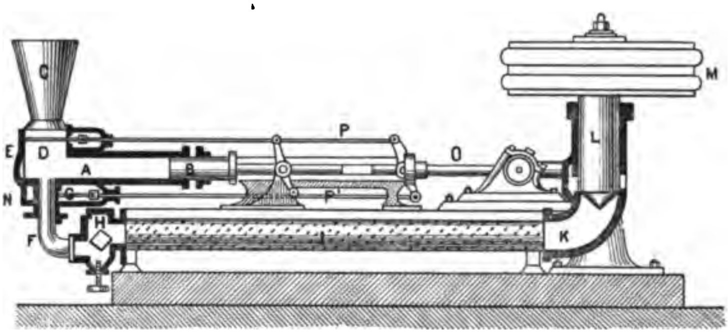
A, cylinder of the counter press *B*; *B*, *C*, bore holes; *D*, valve; *E*, lever with weight; *F*, connecting rod.

Continuous oil presses.—The first continuous oil press was constructed in 1856, by Bessemer & Heywood, of London, but for some reason or another was not introduced in practice. In 1883, F. Müller, of Esslingen, patented a similar press, based upon the same principle. The seed-meal falls continuously through a hopper into a horizontal pipe in which a piston moves backward and forward. By the forward stroke of the piston the seed-meal is forced into a perforated horizontal pipe of somewhat larger cross-section than the first pipe, while by the back stroke more seed-meal is introduced, the process being repeated until expression is finally effected.

Figs. 125 and 126 show the arrangement of Müller's continuous press according to the patents which have now expired.

In the cylinder *A* the piston *B* is moved to and fro by direct steam or water-pressure. On the cylinder *A* is the hopper *C* with the pipe *D*, in which can be inserted the slide *E*. The lower side of the cylinder is correspondingly provided with the pipe-joint *F* and the slide *G*. The seed-meal introduced into the hopper is forced, after the valve *H* is lifted, by the piston *L* into the perforated pipe *I*, which is bent upwards at *K* and there closed by the piston *L*. The piston is loaded with weights, and the pressure of these weights has first to be overcome before the piston is lifted and the aperture *N* for emptying the pipe is opened. In the pipe *I*, the seed-meal is subjected to such a strong pressure as to force the oil through the perforations.

FIG. 125.



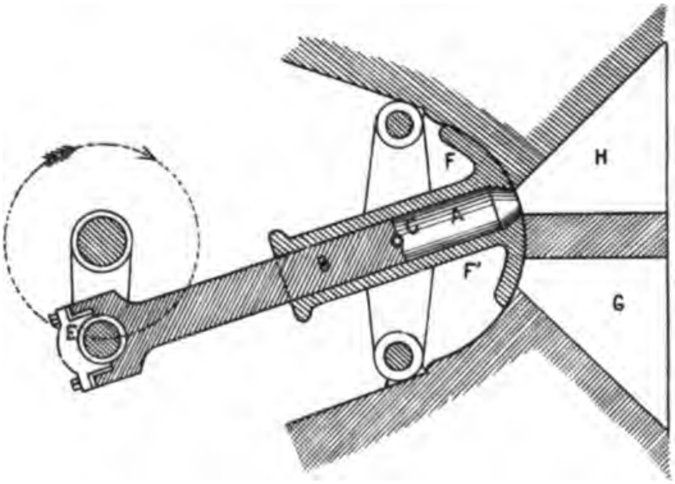
F. MÜLLER'S CONTINUOUS PRESS.

A, cylinder; *B*, piston; *C*, hopper; *D*, pipe; *E*, slide; *F*, pipe joints; *G*, slide; *H*, valve; *I*, perforated pipe; *L*, piston; *M*, weights; *N*, discharge aperture; *O*, piston rod; *P P*, slide rods.

When the greatest pressure in *I* has been attained, the aperture *N* opens by the piston *L* moving upwards, and the expressed material falls out. Hence, over-pressure in *I* is not possible, or at least cannot be communicated to the cylinder *A*, since it would close the valve *H*. Of great importance is the reversing of the slides *E* and *G* by the machine itself, it being accomplished in the original arrangement, Fig. 125, by the slide rods *P P'* from the piston rod *O*, the latter engaging the lower slide-rod *P'*. By the back stroke of the piston *B*, *E* is drawn back; hence *D* is open while *G* is pushed into the pipe *F*.

Fig. 126 shows a more recent arrangement for reversing, by which the press-cylinder *A* can be turned around a point *C*. By the piston *B* passing to and fro an oscillating motion is given to the cylinder *A*. The piston *B* can be turned around the point *D*, and is secured to the crank *E*, which derives its impetus from the machine. In the cylinder *A* are secured the slides *F*, *F'*. With the back stroke of the piston *B*, the cylinder moves so that the slide *F'* closes the discharge-aperture *G*, while the mouth of the cylinder is brought into communication with the hopper *H*. With the forward stroke of the piston the position is reversed.

FIG. 126.



F. MÜLLER'S CONTINUOUS PRESS.

A, press-cylinder; *B*, piston; *C*, *D*, turning points; *E*, crank; *F*, *F'*, slides; *G*, discharge aperture; *H*, hopper.

Pumping Machinery.—This forms the other essential portion of hydraulic presses.

Figs. 127 and 128 show pumping machinery with two pumps, according to A. Rigg.

Upon the shaft *A*, on the side of the pump frame *H*, sit the loose and fast pulleys *B* and *C* for the transmisson of motion from the principal shaft. Upon the shaft *F*, which is put in motion by cog-wheels *D*, *E*, sit two cranks which move the piston.

FIG. 127.

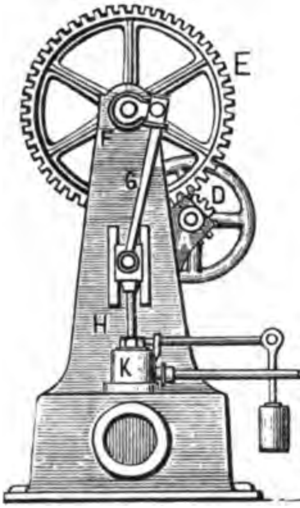
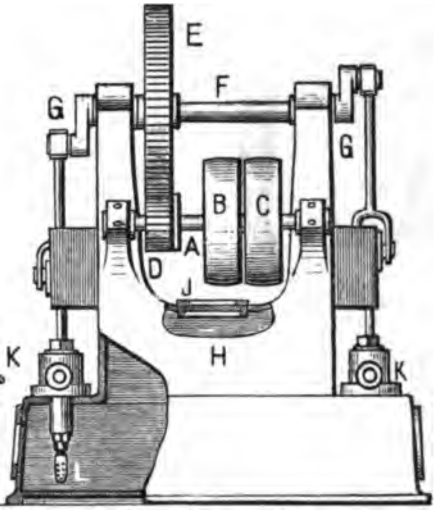


FIG. 128.



PUMP.

Front view. *Side view.*

A, shaft; *B*, *C*, loose and fast pulleys; *D*, *E*, cog-wheels; *F*, crank shaft; *G*, cranks; *H*, frame; *J*, lid; *K*, pumps; *L*, suction head.

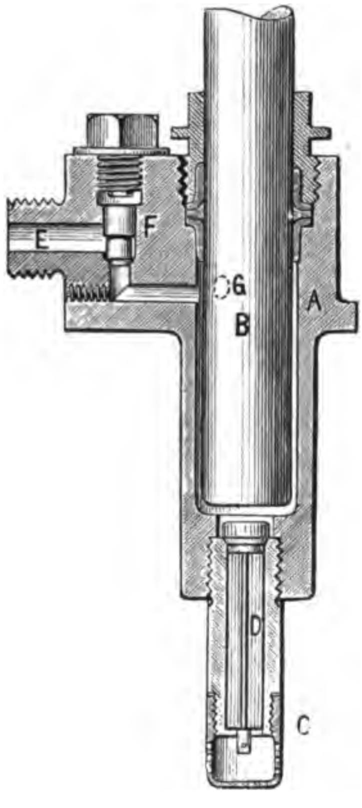
The frame *H* is made in the form of a box and serves as a reservoir, from which the pump takes the water by means of the suction heads *L*. The box is filled after removal of the lid *J*.

Figs. 129, 130, and 131, show the details of the above pump-work.

The piston *B* runs in a brass stuffing box with leather packing. On the lower end of the cylinder is the bucket *C*, which contains the suction valve *D*.

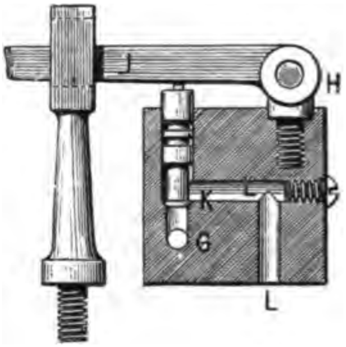
To *E* is screwed the pipe conduit leading to the press; *F* is the delivery valve. On the conduit *G* is a safety-valve which is pressed upon its conical seat by the lever *J* turnable in the eye *H*, and a weight not shown in the illustration.

FIG. 129.



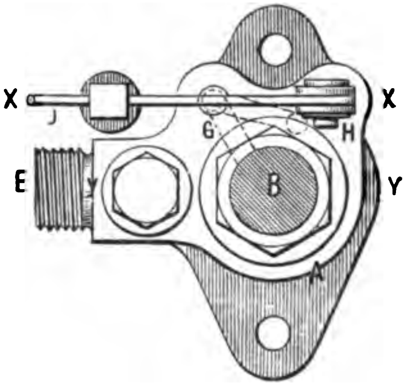
SECTION THROUGH THE PUMP IN THE DIRECTION OF *Y Y*.

FIG. 130.



SECTION THROUGH THE SAFETY-VALVE IN THE DIRECTION OF *X X*.

FIG. 131.



GROUND-PLAN.

A, press cylinder; *B*, piston; *C*, bucket; *D*, suction valve; *E*, delivery pipe conduit; *F*, delivery valve; *G*, conduit; *H*, turning eye of the lever; *J*, lever; *K*, safety-valve; *L*, discharge pipe.

But little power being required in the early part of the operation, on account of the slight resistance offered by the meal, the piston is forced upward with comparative velocity by operating both pumps. But, as the resistance becomes greater the more the meal is pressed, the large pump is stopped and the operation continued with the small one alone. By these means the piston is raised slowly, but with an increased pressure.

To prevent the pressure from exceeding a definite maximum each pump is provided with a safety-valve *K;* should the pressure become too great in the cylinder or any of the conduits, the water will finally overcome the weight *J* and raise the valve. Sufficient water then escapes through the discharge pipe *L* to restore the normal pressure, after which the weight presses the valve back into its seat.

Pumping machinery with eight pumps for eight vertical presses is shown in Figs. 132 and 133. The eight pumps lie in a cast-iron box, and are suspended to two beams, four on each beam. The two beams are set in an oscillatory motion from the principal gearing, so that one-half of the active pumps suck while the other exert pressure, the working resistance of the pumping machinery being thus approximately constant. A power of about 10.6 horse-powers is required.

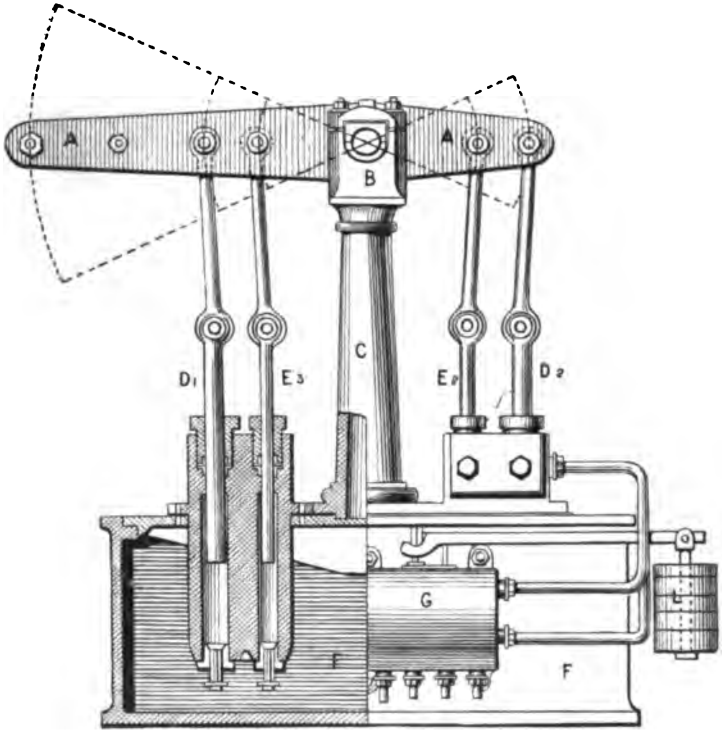
The pumps with a reservoir in common are provided with self-acting disengaging contrivances so arranged that the total resistance is as little variable as possible.

The time of pressure is divided in four periods, all the eight pumps—of which there are four larger ones with a piston-diameter of 1.96 inches, and four smaller ones with a piston-diameter of 1.37 inches—being at first set to work. The maximum pressure amounts to 280 atmospheres, the pressure exerted during the first period being up to 46.6 atmospheres; during the second period up to 70.0 atmospheres; during the third period up to 140.0 atmospheres.

The first period of pressure lasts 48 seconds, the second 46, the third 205, and the fourth 241; together 540 seconds = 9 minutes.

One smaller and one larger pump have together one delivery-pipe, the four delivery-pipes passing into a collecting box, Figs. 134 and 135. From the collecting box *G* eight delivery conduits lead to the eight vertical presses worked by this pumping machinery. The collecting-box is provided with two safety-valves *K* with the weights *L*.

FIG. 132.

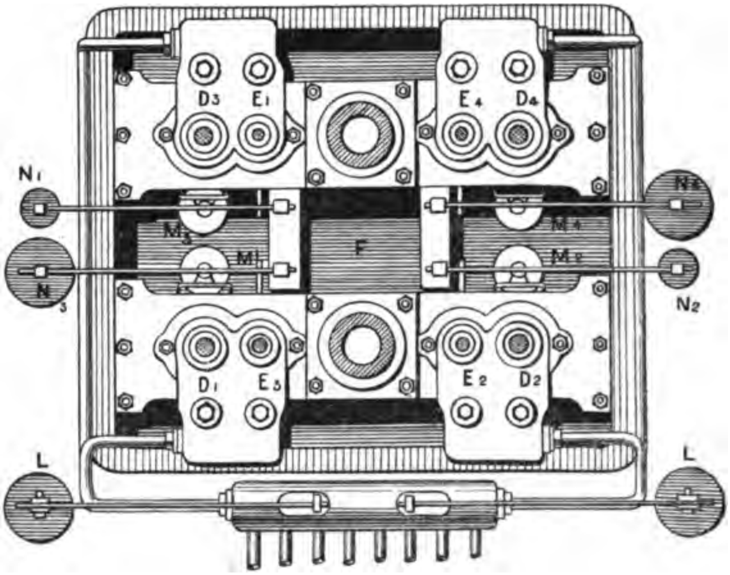


PUMPING MACHINERY WITH 8 PUMPS. VIEW AND SECTION.

The self-acting disengaging contrivance of the pumps is arranged as shown in Figs. 136 and 137.

Upon one end of the lever *R*, which rests in the reservoir *F*, and is suspended to the fulcrum *S* like the beam of a balance, presses the weight *M*; in about the center of the lever sits the suction valve *P*, while on the other side the lever is further suspended to a closely-fitting piston *O*.

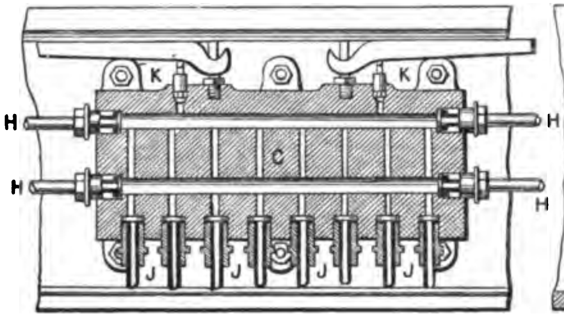
FIG. 133.

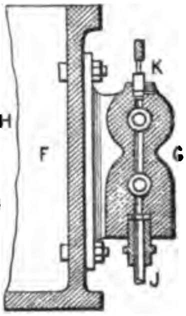


PUMPING MACHINERY WITH 8 PUMPS. GROUND-PLAN.

A, beam; *B*, beam-bearing; *C*, columns; *D*, to D_4, the four larger pumps; *E*, to E_4, the four smaller pumps; *F*, reservoir; *G*, collecting reservoir; *K*, safety-valves; *L*, weights of safety-valves; *M*, to M_4, weights of the disengaging contrivance of the larger pumps; *N*, to N_4, weights of the disengaging contrivance of the smaller pumps.

FIG. 134. FIG. 135.



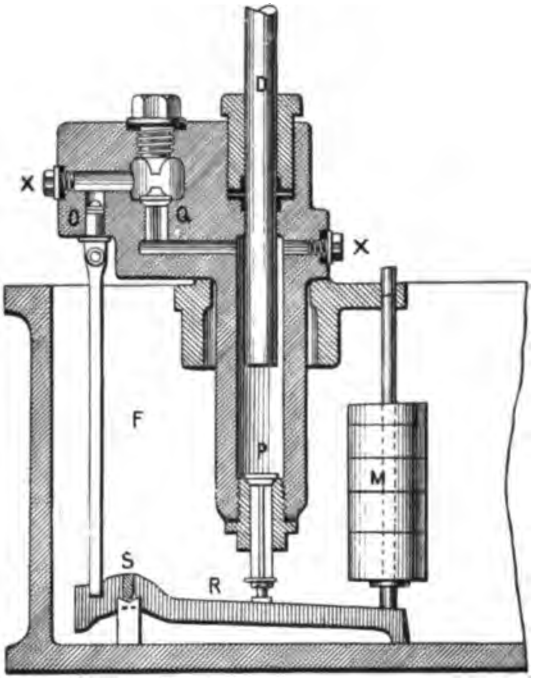


COLLECTING-BOX OF PUMPING MACHINERY.

Longitudinal section through the centre. *Cross section.*

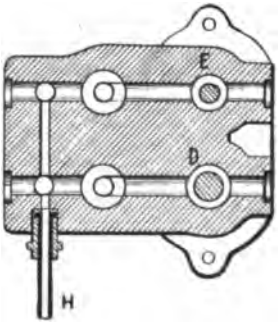
F, reservoir; *G*, collecting-box; *H*, delivery pipes to the collecting-box; *J*, delivery pipes to the presses; *K*, safety-valve.

FIG. 136.



Section through the center.

FIG. 137.



Section in the direction of X X.

PUMPS WITH SELF-ACTING DISENGAGING CONTRIVANCE.

D, larger pump; E, smaller pump; F, reservoir; H, delivery pipe to the collecting-box; 'M, weights for disengaging the larger pump; O, piston of the disengaging contrivance; P, suction valve; Q, delivery valve; R, lever; S, fulcrum of lever.

If now the pressure in the pump becomes so great as to force the piston *O* down, the lever *R* goes up and lifts the weight *M* as well as the suction valve *P*, the latter remaining open.

Thus the pump sucks and forces the sucked water through the open valve *P* back into the reservoir; the delivery valve *Q* remaining thereby closed, so that the pump cannot produce any further effect.

Since the smaller pumps are disengaged only at a higher pressure, another lever-gearing is provided, for which smaller weights are to be used.

The weights are so calculated that the pumps E_1 and E_2 are disengaged, next E_3 E_4, and D_1 D_2, while the pumps D_3 and D_4 work finally alone with a maximum pressure of 280 atmospheres.

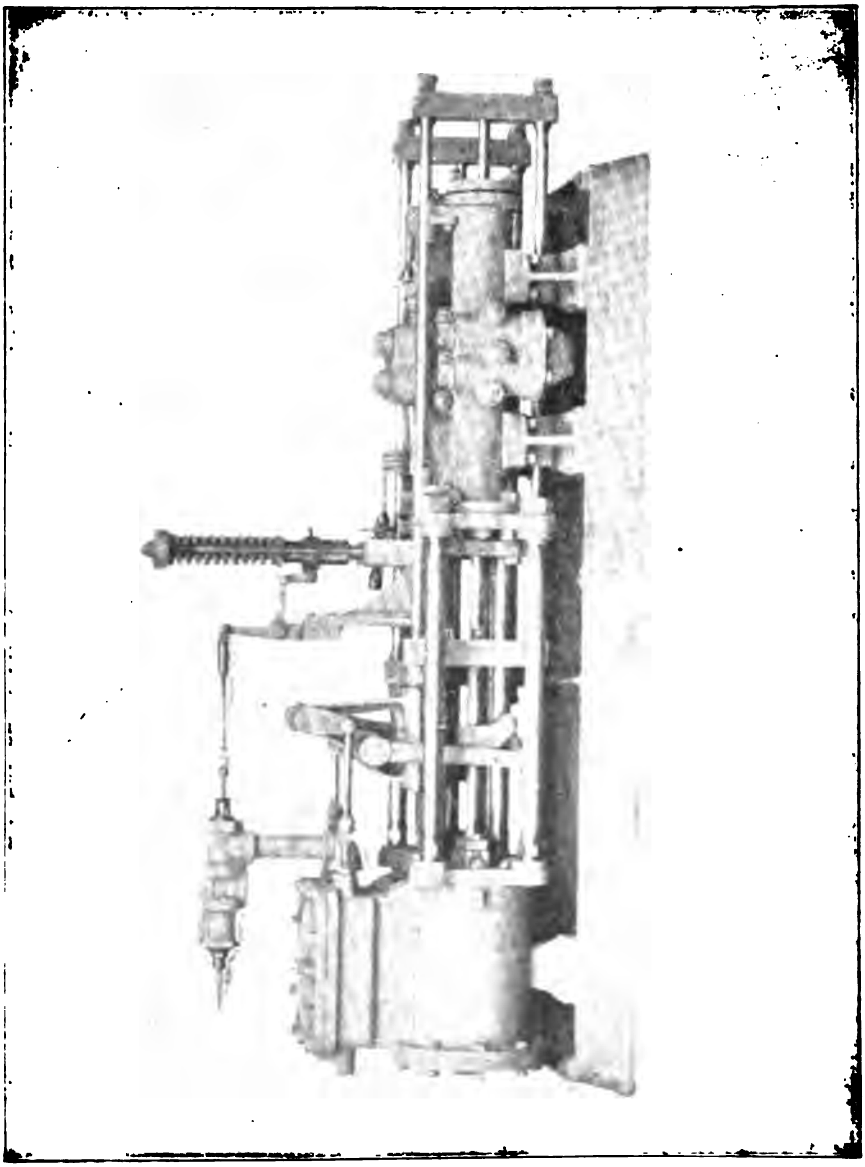
Fig. 138 exhibits the Smith-Vaile Duplex Hydraulic Pressure Steam Pump, with automatic governor and regulator.

This pump has the improved duplex valve connections, with outside connected double acting plungers for the water end, and external adjustable packing glands for the plungers, which are readily renewed. The valve boxes are made of gun metal and the plungers of steel. It is a desirable form of steel pump for operating hydraulic presses, as its action is positive at an increasing pressure, or in maintaining an even pressure. When desired it is arranged to automatically maintain any required pressure, stopping when the limit is reached, and starting as soon as the pressure falls.

By its use the maximum working pressure and the accumulation of pressure is absolutely controllable by the manager or engineer.

Automatic safety arrangements, which disengage the hydraulic presses after the attainment of the maximum pressure, allow of this limit being reached for a moment only, after which the press ceases to act. Though the meal continues to be somewhat compressed by the ram still ascending, the pressure in the cylinder will considerably decrease as the pump stops to bring fresh water.

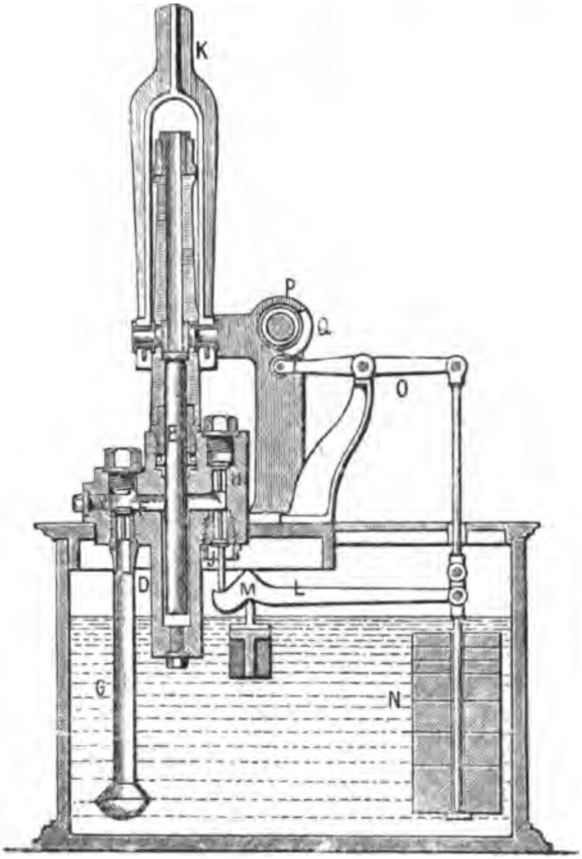
FIG. 138.



THE SMITH-VAILE DUPLEX HYDRAULIC PRESSURE STEAM PUMP.

It is, however, desirable to expose the meal to the highest pressure for some time in order to express as much oil as possible.

FIG. 139.



PRESSURE REGULATOR.

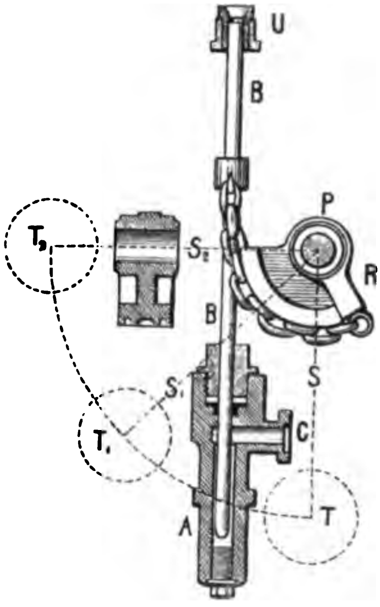
A, cylinder of the regulator; *B*, regulator piston; *C*, flange for fastening to the delivery pipe; *D*, cylinder; (*E*, piston; *F*, suction valve; *G*, suction pipe with bucket; *H*, delivery valve; *J*, safety-valve; *K*, crank rod of press-pump;) *L*, lever; *M*, sheath; *N*, weights; *O*, lever of the regulator; *P*, shaft; *Q*, eccentric; *R*, quadrant with chain; *S*, lever; *T*, weight; T_1, T'_2, positions of weight; *U*, stuffing box for the regulator piston.

For this a safety-valve, shown in Figs 139 and 140, and arranged in the following manner, is used.

In the delivery pipe of the coöperating pumps, if several are used at the same time, is screwed a cylinder *A* with the piston *B* through the flange *C*.

D represents one of the pump cylinders, *E* the piston belonging to it, *F* the suction valve, *G* the suction pipe with bucket, *H* the delivery valve, and *J* the safety-valve. The crank rod *K* moves the piston.

FIG. 140.



SECTION THROUGH THE CYLINDER OF THE REGULATOR.

The safety-valve *J* stands upon the lever *L*, which rests upon *M*, and to the long arm of which are suspended the weights *N*.

The weights are so calculated that they keep the safety-valve in its seat as long as the maximum of the water pressure is not reached in the delivery pipe and the press. The weights are, however, also suspended to one arm of the lever *O*, the other arm being provided with a pulley.

A shaft P carrying an eccentric Q for each pump and a quadrant R rests in standards. To R is suspended a chain, the other end of which catches into a hook in the piston B.

To the shaft is firmly attached a lever S (not shown in the illustration) with the weight T. The piston B runs in the stuffing box U.

With an increase of pressure, the piston B ascends, which causes the quadrant R to turn, and the weight T ascends from T to T_1, whereby the eccentrics are also turned.

If, for instance, two pumps are coupled, and one is to be disengaged before the other, the eccentric belonging to the first pump is so wedged upon the shaft P as to press down the pulley of the lever O, thus raising the weight N when the weight T has ascended to T_1.

The eccentric of the second pump is so wedged upon the shaft that the weight N belonging to it is disengaged when the weight T has reached T_2.

Now as soon as the weight N is raised by an eccentric, the safety-valve is opened by the pressure in the delivery pipe, and the respective pump is disengaged. By this the piston B falls down and replaces in the press as much water as it forces out of the cylinder A, thus keeping up the maximum pressure.

In this manner the pump is also re-engaged, because the weight N closes the safety-valve, and the pump can again convey water through the delivery pipe previously closed by the delivery valve.

The regulator piston B acts therefore automatically by replacing water in the press, thus keeping up the pressure.

Accumulators. To keep up a constant pressure in the press accumulators, Figs. 141 and 142 are used.

In a tall cast-iron cylinder A moves water-tight a piston B, while a second cylinder C, which can easily slide up and down on A, carries a number of weight-disks D. A cross-head is fastened upon the piston B, and to it are suspended three rods F, which pass through the weights D and are fastened to the cylinder C.

Hence the piston in ascending draws up the cylinder *C* and the weights *D*.

The apparatus is inserted between the injecting pump and

FIG. 141.

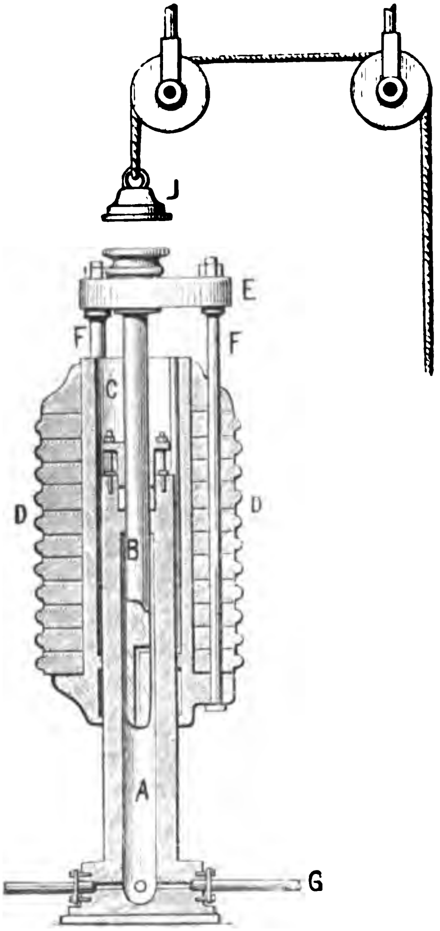
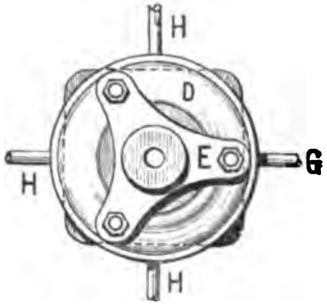


FIG. 142.



ACCUMULATOR FOR HYDRAULIC PRESSES.

Vertical section. *Ground-plan.*

A, inner cylinder; *B*, piston of *A*; *C*, water cylinder; *D*, weight-disks; *E*, cross-head; *F*, connecting rods; *G*, pipe from the pump; *H*, pipe to the presses; *J*, weight.

the hydraulic press, so that the water coming from the first is conducted through the pipe *G* into the cylinder *A*, and then through the pipes *H* into the cylinder of the respective working press.

If, therefore, the pressure of the water coming from *G* exceeds the weight of the disks *D*, the cylinder *C*, the piston *B*, the cross-head *E*, and the rods *F*, it will raise the entire weight; but if the total weight be larger than the water pressure, the piston, with its load, will sink.

The weights act as regulators by exerting a constant pressure upon the water, because every pressure exerted by the pump and not absorbed by the press reaches the accumulator as pumped-in water and lifts the total weight, while the latter, in case more pressure is consumed by the press than furnished by the pump, again exerts pressure by sinking down.

When the piston *B* reaches its highest stroke, the press water is discharged through a hole on the lower end of *B* without causing any injurious effect.

To disengage the pump after the attainment of a certain height by the accumulator weight, a shoulder of the cross-head pushes against the weight *J*, suspended to a cord. The cord is connected with the suction-valve of the pump, so that when the cross-head *E* pushes against the weight *J*, thereby lifting it, the cord unshackles the valve, thus stopping the pump.

If the total weight of the disks *D*, cylinder *C*, piston *B*, cross-head *E*, rods *F* is 3300 kilogrammes, and the cross-section of thepiston = 33 square centimetres, the press belonging to it will receive a constant pressure of

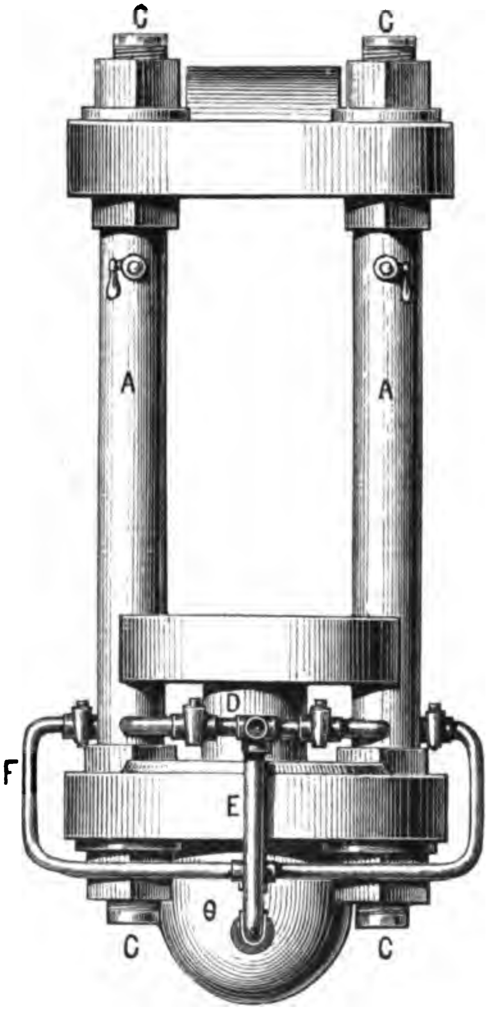
$$\frac{3300}{33} = 100 \text{ kilogrammes per square centimetre,}$$

or, as a pressure of one kilogramme per square centimetre corresponds to that of one atmosphere, the constant pressure in the press will be 100 atmospheres.

By varying the number of the disks *D* this pressure can be decreased or increased.

Besides by weights in the manner described, a constant pressure can also be obtained by an air reservoir in which the air

Fig. 143.

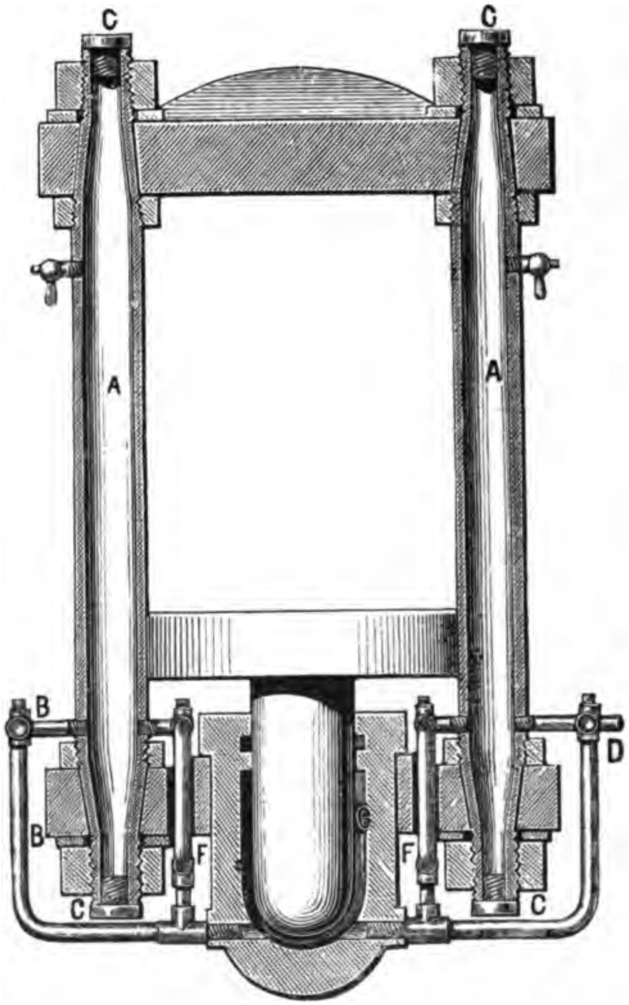


ACCUMULATOR ARRANGEMENT, BARTLETT'S PATENT. SIDE VIEW.

A, anchor bolts; *B*. connecting pipes; *C*, locking screws; *D*, conduit from the pump; *E*, direct conduit to the press; *F*, conduit from the accumulator to the press; *G*, press cylinder.

is compressed by the water from the pump. The compressed

FIG. 144.



ACCUMULATOR ARRANGEMENT, BARTLETT'S PATENT. SECTION THROUGH THE PRINCIPAL VIEW.

air acts then, as in the air chamber of a pump, as a regulator, since, by an augmentation of the water pressure by an increase of the power introduced into the pump, this water pressure is utilized to further compress the air. By this operation the overpressure is therefore utilized without an unnecessary and dangerous demand on the press.

If, as is generally the case, these air reservoirs form a special apparatus, they must be provided with a manometer constantly showing the pressure of the air, and a safety-valve which opens when the air is too strongly compressed, and decreases the pressure by allowing the air to escape.

H. J. Bartlett, of New York, has patented an arrangement (Figs. 143 and 144) by which the accumulator, being directly connected with the press, is very much simplified.

The anchor bolts *A* of the hydraulic press are hollow and together form the air chamber. They are connected with each other by the pipes *B*, which are provided with cocks.

The bolts are of wrought iron and closed on both ends by screws *C*.

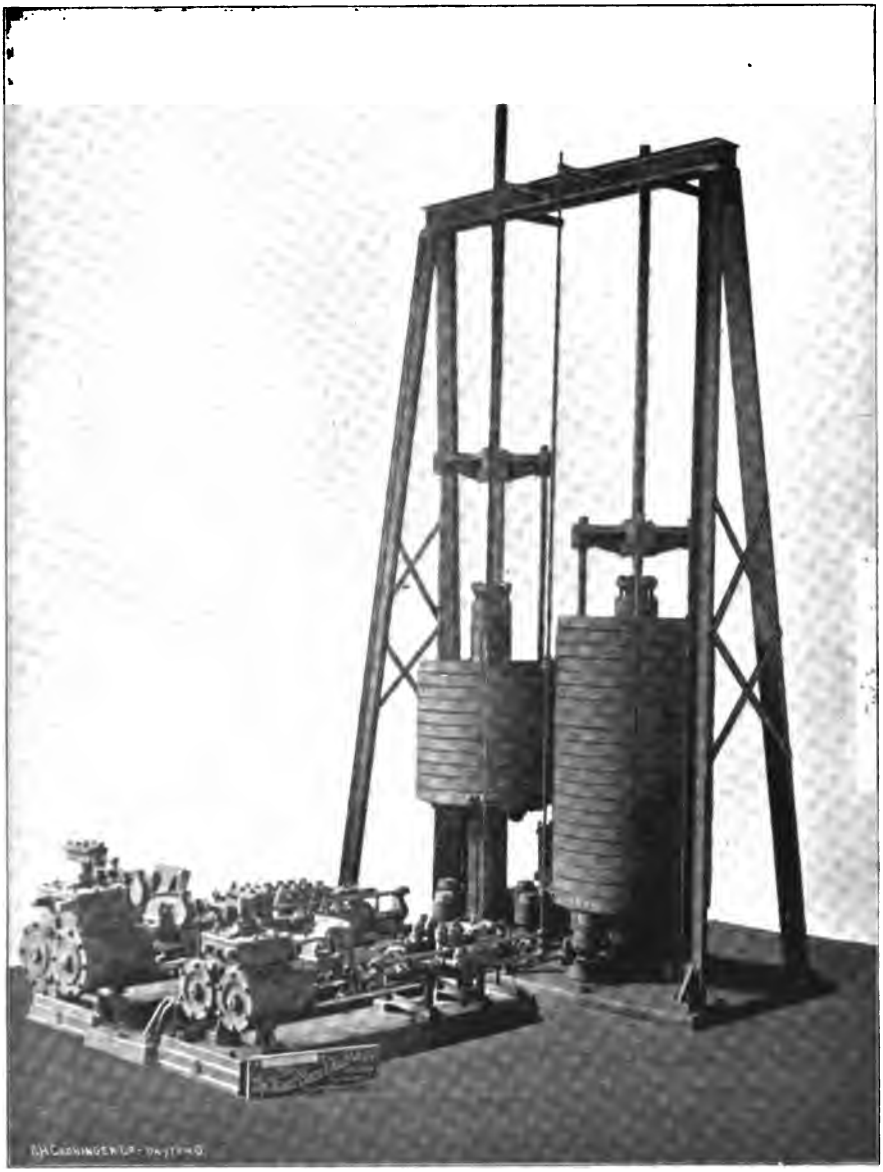
The press-water comes through the pipe *D* from the pump, and can also be directly conducted into the press through the pipe *E*.

From the accumulator pipes the water then enters the press cylinder *G* through the pipe *F*. Each bolt must, of course, be provided with the above-mentioned armature.

Fig. 145 represents the Smith-Vaile High and Low Pressure Accumulator System. The apparatus consists of high pressure and low pressure weight accumulators, with powerful steam pumps attached and arranged with automatic regulating device to stop the pumps when the pressure has reached a certain desired limit. By using this system the hydraulic presses can be operated by accumulator pressure, which in the low pressure accumulator is from 600 to 800 pounds, and in the high pressure accumulator is about 3500 pounds. The chief advantage of the accumulator system is, of course, the rapid operation thereby made possible, effecting a great saving of time, especially in the working of the press.

Hydraulic presses without pump-work.—The old hydraulic

FIG. 145.

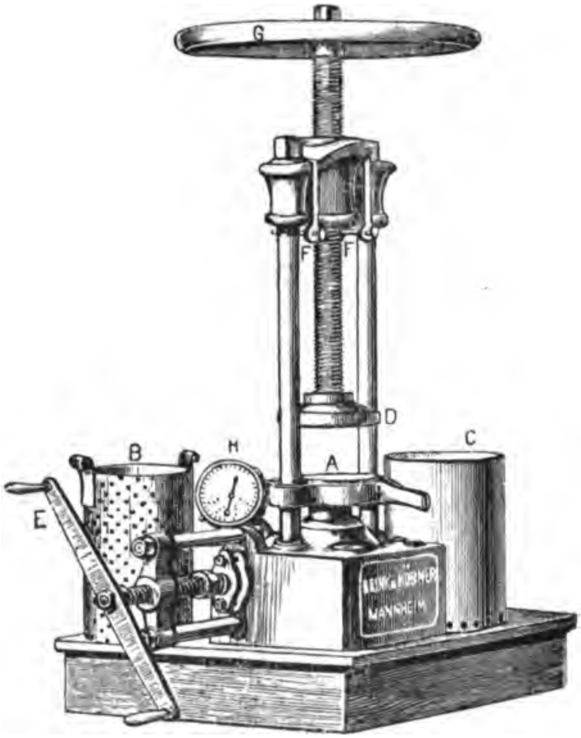


THE SMITH-VAILE ACCUMULATOR SYSTEM.

presses without pump are so constructed that a large vertical press cylinder is connected by an opening with a smaller cylinder.

Both cylinders are provided with corresponding small rams and filled with liquid, which, by inserting the ram, is displaced and acts upon the large ram.

FIG. 146.



HAND-PRESS WITHOUT PUMP.

A, ram with press-plate; *B*, press vessel; *C*, jacket; *D*, upper press-plate; *E*, crank; *F*, stays; *G*, lever; *M*, manometer.

Fig. 146 shows a hand-press without pump. The lower part consists of two cylinders connected by a tube and filled with glycerin. Both cylinders are provided with well-packed rams, the larger of which *A*; carries the press-plate. Upon the press-plate stands a perforated cast-iron vessel *B*, which holds the meal separated in layers by plates. To prevent squirting the jacket *C* is placed over *B*. The upper press-plate *D*, connected with a vertical screw, is then forcibly brought down by the lever *G*, whereby the pressure of an ordinary screw-press is already exerted. But the principal pressure is effected by turning the crank *E* connected with the lower horizontal screw, whereby the small ram is forced into its cylinder, which produces a tension of 300 atmospheres in the glycerin. The pressure, which is controlled by a manometer, is transmitted by the vertical ram to the mass to be pressed. The cake is removed from the press-box by suspending the latter by means of two loops in the traverse to the two stays *F* and screwing down the press-screw.

To exert a further pressure the small ram is entirely withdrawn, the press-plate being screwed down at the same time. The ram is then again forced into the glycerin until the manometer shows a pressure of 300 atmospheres.

This mode of pressing requires much time and is not suitable for large operations. To overcome this, Messrs. Brink and Huebner, of Mannheim, Germany, have constructed a press with two or more cylinders placed on the side of the large cylinder.

Figs. 147, 148, and 149, show such a press driven by a belt.

The press-cylinder *A*, ram *B*, and head *C* are connected in the usual manner. In the head *C* is the box of a rectangular screw *D*, which can be moved by hand by means of the rods *E*.

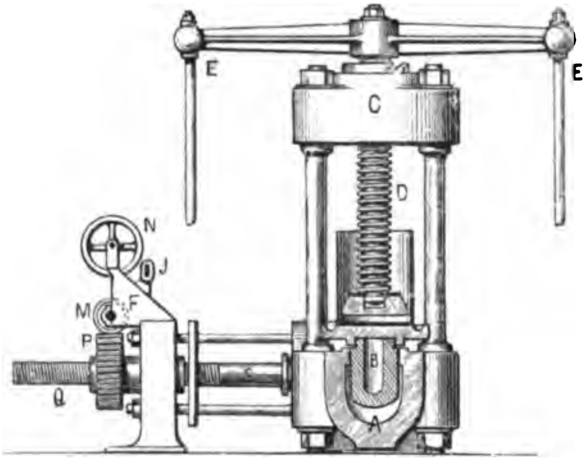
The arrangement is similar to that of a box-press.

Upon the driving shaft *F*, Fig. 148, sit four pulleys, G_1 and G_2 for forward motion and H_1 and H_2 for backward motion, G_1 and H_1 being fast and G_2 and H_2 loose. The belts are shifted by the guide *J*, so that the press can be either operated or stopped.

On the side of the cylinder *A* are two smaller cylinders *K* and *L*, with different sized pistons *S* and *T*.

Upon the shaft *F* sit two worms *M;* when, by means of the small hand-wheel *N*, the coupling *O* is engaged, the worms *M* are taken along by the shaft by means of friction coupling, and in their turn revolve the worm-wheels *P*, and these forming the nuts of the screws *Q* and *R*, the latter are moved backward or forward by the revolving of *P*.

FIG. 147.



BRINK AND HUEBNER'S PRESS WITHOUT PUMP. SECTION THROUGH THE CENTRE.

A, press cylinder; *B*, ram; *C*, head; *D*, screw with press-stamp; *E*, rods; *F*, driving shaft; G_1, G_2, belt pulleys for forward motion; H_1, H_2, belt pulleys for backward motion; *J*, belt guide; *K*, *L*, small cylinders; *M*, worms; *N*, hand-wheel; *O*, friction coupling; *P*, worm wheels; *Q*, *R*, screws; *S*, *T*, rams of the small cylinders.

By the forward motion the rams *S* and *T* are forced into the cylinders *K* and *L*, filled with a liquid (glycerin), forcing the latter into the cylinder *A*, where the rams with the box containing the meal are raised and pressed against the press-stamp on the screw *D*. The larger ram *S* is first forced in, and later on the smaller ram *T*, to withdraw *S*. The screw *D* can always be regulated by *E*.

By the small hand-press (Fig. 146) a pressure of about 220 pounds per 0.155 square inch is exerted, and two pressures can be made in one hour.

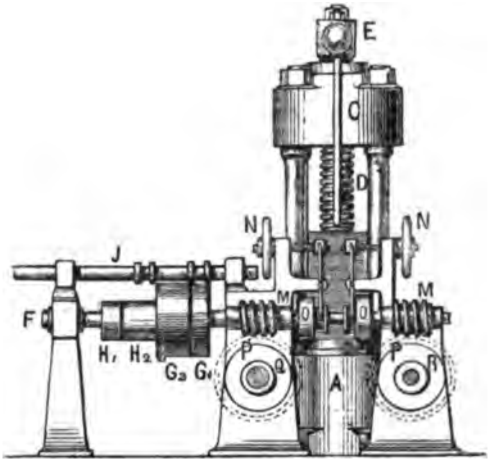
By the large press a pressure of about 350 pounds per 0.155

square inch can be obtained, and three to four pressures made in one hour.

Press-cloths and Press-plates.

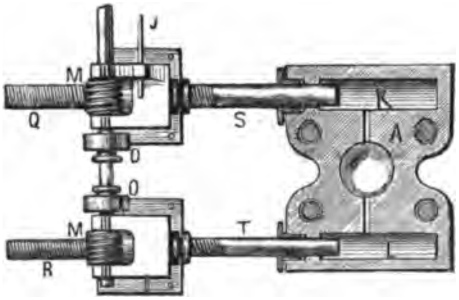
The material used in the manufacture of press-cloths and bags should be capable of great resistance, and, while close enough to prevent any meal from penetrating, allow the oil to run out as freely as possible; properties not readily found combined in any one material.

FIG. 148.



SIDE VIEW.

FIG. 149.

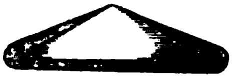


HORIZONTAL SECTION THROUGH THE PRESS CYLINDER.

The most suitable materials are cotton, sheep's wool, and horsehair.

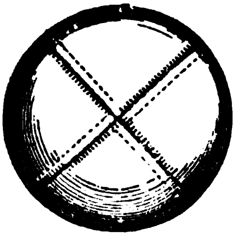
Figs. 150 and 151 give a side and top view of a press-bag. It has a plate-shaped bottom with a stiff edge, while the upper portion consists of overlapping pieces, which, after the meal is filled in, are folded over each other as shown in Fig. 106.

FIG. 150.



PRESS-BAG. SIDE VIEW.

FIG. 151.



PRESS-BAG. TOP VIEW.

The press-plates (Figs. 152 to 156), between which the filled bags are placed, are frequently ribbed to promote the running off of the oil in pressing. These ribs penetrate through the press-cloth and give to the oil cake the ribbed surface; but the bags are ruined so that they can scarcely be used for another operation.

C. S. Brittain and M. Gandy, of Liverpool, have, however, patented a method of manufacturing press-cloths with the aforementioned ribs.

Fig. 157 shows two sections of this cloth taken from different places.

The press-cloth is made by sewing together a cloth *A*, of canvas, and one *B*, of wool, between which are placed ropes *C* wrapped with cord *D*, thus forming on both sides rib-like elevations.

Fig. 158 shows a press cloth with elevations on one side only. It is made by sewing together the cotton canvas cloth *A* and the woolen cloth *B*. The elevations are formed by placing ropes of pressed paper, wood, cord, etc., between the cloths.

After filling the press-cloths and placing them between the

FIG. 152.

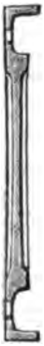


FIG. 153.

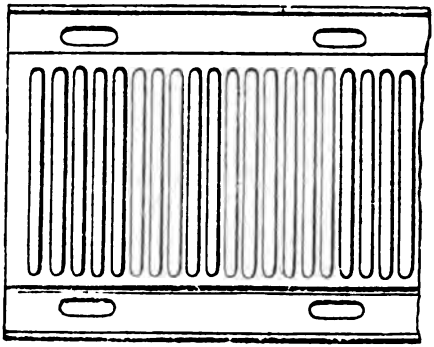


FIG. 155.

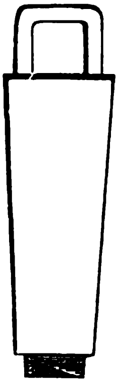


FIG. 156.

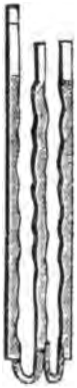
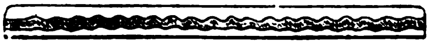


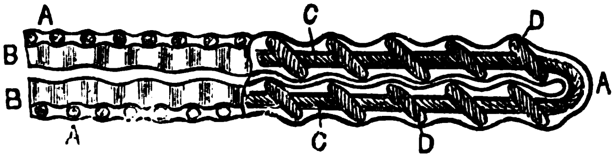
FIG. 154.



PRESS-PLATE. VIEW AND SECTION.

PRESS-PLATE. LONGITUDINAL AND CROSS SECTION.

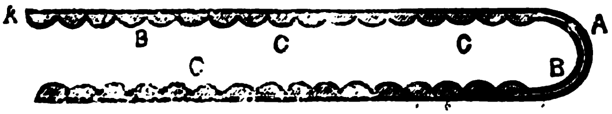
FIG. 157.



PRESS-CLOTH. SECTIONS.

A, canvas tissue; *B*, wool or horse-hair tissue; *C D*, ropes.

FIG. 158.



PRESS-CLOTH.

A, cotton canvas tissue; *B*, woolen tissue, *C*, ropes.

plates, the latter have to be coupled together. This was formerly effected by chains or leather straps. But the first have the disadvantage of stretching unequally, so that cakes of different shapes are formed, which are not salable. And besides, the links of the chains frequently break by coming under the press-plates in placing the bags in the press, and they are difficult to unfasten. Leather, when used, soon becomes spongy by the action of the oil, and breaks.

A coupling free from these evils is shown in Figs. 159 and 160.

FIG. 159.

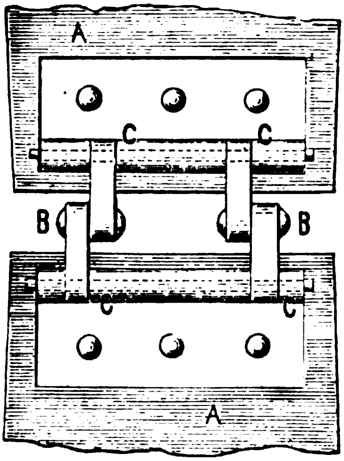
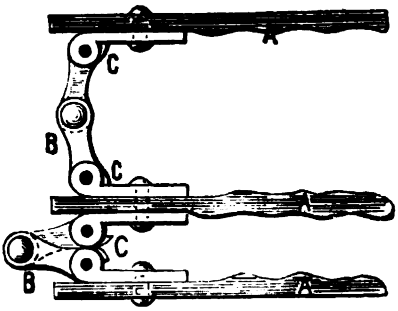


FIG. 160.



PRESS-PLATE COUPLING.

View. *Section.*

A, form-plate; *B*, hinge; *C*, catch.

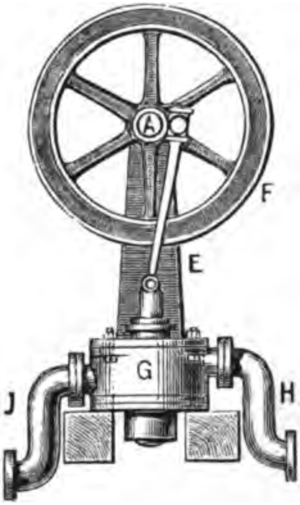
To the form-plates *A* are riveted loops to which are fastened the double-hinged bands *B*. The stroke of the hinge parts is limited by the catches *C*, the object of which is to prevent the coupling from coming between the plates *A* and breaking in pressing.

In order not to lose the oil retained by the press-bags they are uninterruptedly used as long as they can be repaired. When entirely worn out the oil is saponified by boiling the bags with dilute caustic soda lye.

Oil Pump.

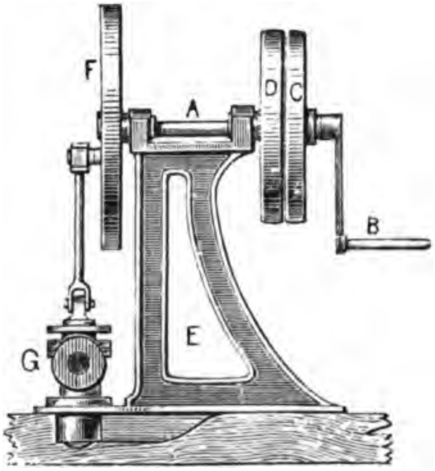
To convey the oil from the collecting reservoirs into barrels or refining reservoirs, a pump, Figs. 161 to 164, is used. It

Fig. 161.



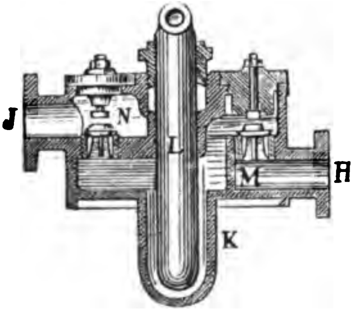
OIL PUMP. FRONT VIEW.

Fig. 162.



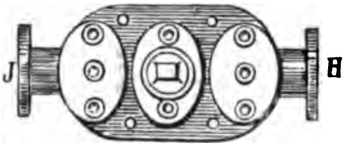
SIDE VIEW.

Fig. 163.



SECTION THROUGH THE CENTRE.

Fig. 164.



GROUND-PLAN OF PUMP *G*.

A, crank shaft; *B*, crank; *C*, *D*, loose and fast pulleys; *E*, frame; *F*, fly-wheel; *G*, pump; *H*, suction pipe; *J*, delivery pipe; *K*, pump cylinder; *L*, piston; *M*, suction valve; *N*, delivery valve.

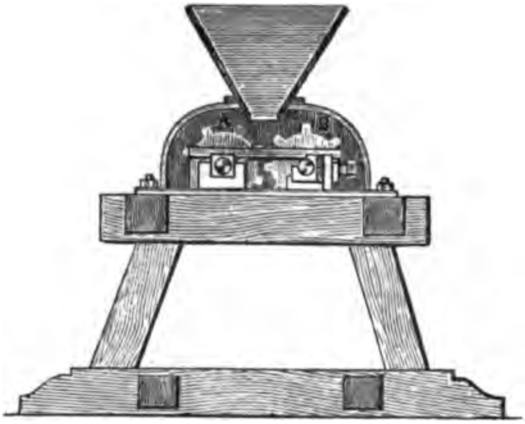
can be worked either by hand, by means of the crank *B*, which sits upon the shaft *A*, or by a belt passing over the fast and loose pulleys *C*, *D*.

When the piston *L* moves upwards, the pump sucks oil from the suction pipe *H*, by means of the valve *M*, and forces it through the delivery valve *N* into the delivery pipe *J*.

Oil-cake Breaker.

For the second pressure the oil-cakes were formerly broken to pieces with a hammer and then ground, but now oil-cake breakers, Figs. 165 and 166, are used in almost all mills.

FIG. 165.



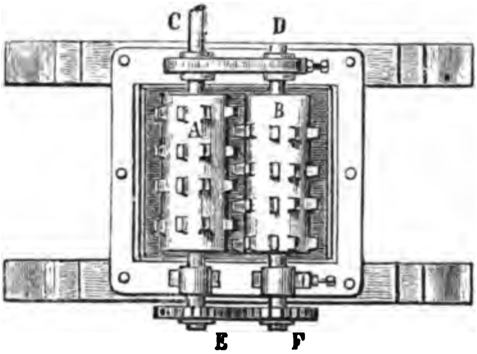
OIL-CAKE BREAKER. CROSS SECTION.

The cakes are brought through the hopper between the toothed rolls *A* and *B*, each of which is provided with 32 teeth, and is, independent of the height of the teeth, about 7½ to 8 inches in diameter, and 21 to 24 inches long. The shafts *C* and *D* are placed square in the rolls, *C* being elongated and connected with a drum, whereby 32 revolutions per minute can be made. On the opposite side of the drum is the cog-wheel *E*, which, by catching into the cog-wheel *F*, sets also the shaft *D* with the roll *B* in motion.

The cog-wheels are about 10 inches in diameter, and provided each with 24 cogs.

Carr's disintegrator.—This machine, Figs. 167 and 168, intended for comminuting all sorts of non-fibrous material, may also be used for breaking up press-cakes from the first, as well as the second, pressure. It consists of two disks *A* and *B* standing opposite to one another. These disks are furnished with rods *D* standing in concentric circles and reaching almost from

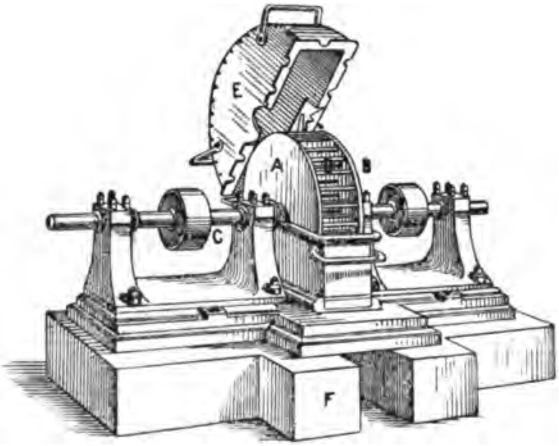
FIG. 166.



OIL-CAKE BREAKER. GROUND-PLAN WITHOUT HOPPER.

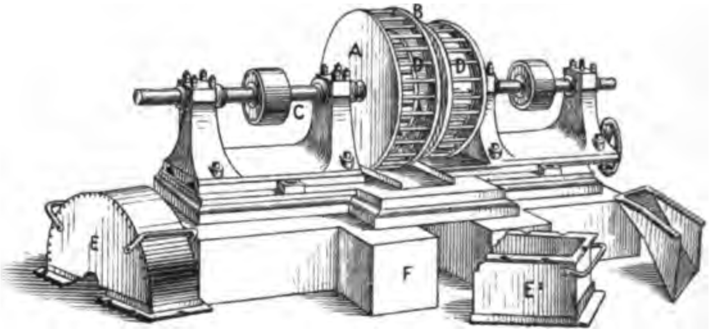
A and *B*, toothed rolls; *C* and *D*, shafts; *E* and *F*, cog-wheels.

FIG. 167.



DISINTEGRATOR: WITH THE COVER RAISED.

FIG. 168.



DISINTEGRATOR: WITH BASKET PUSHED APART.

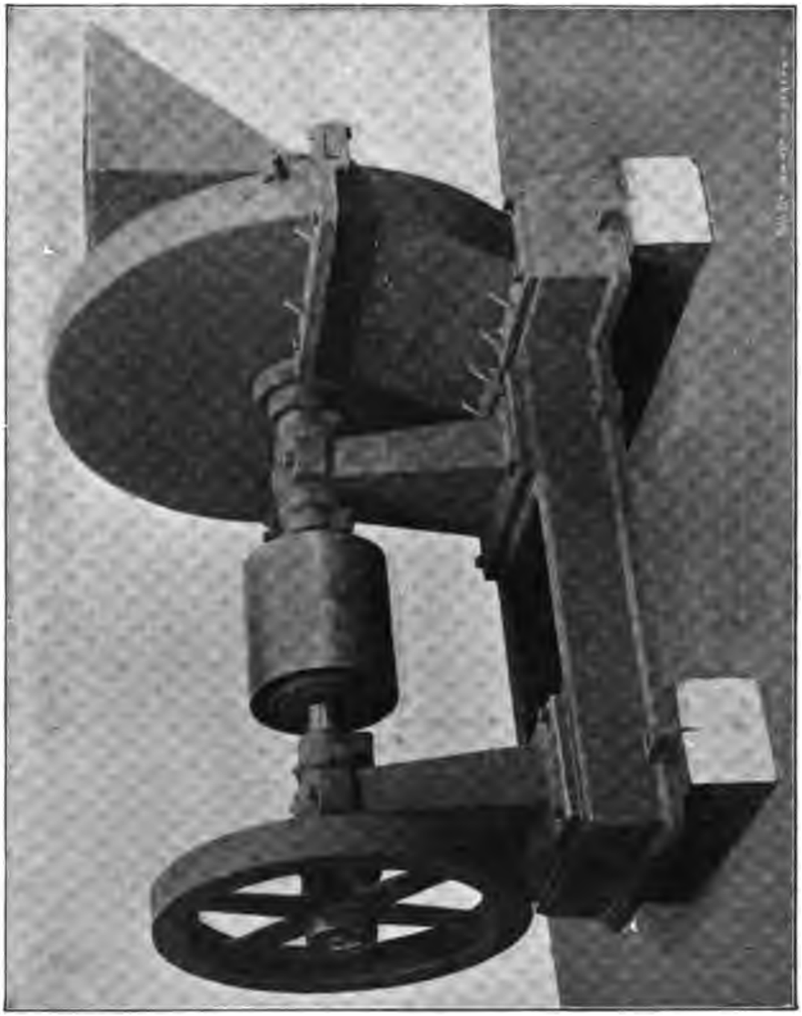
A, *B*, disks; *C*, shaft; *D*, rods; *E*, cover; *F*, frame.

one disk *A* to the other disk *B*; they are fastened only on one end. The disks revolve with great rapidity in opposite directions around the horizontal shaft *C*. The oil-cakes to be comminuted are introduced near the centre of the disks; they are forced outward by the centrifugal force, and, after coming repeatedly in violent contact with the rods, arrive in a comminuted state at the periphery of the disks. The disintegrator thus works solely by impact, there being no grinding by friction between two surfaces, since the rods do not touch one another.

In a disintegrator 4¾ feet in diameter making 400 revolutions per minute, the velocity of each rod in the innermost ring is 52 feet per second; in the second 62 feet; in the third 72 feet; and in the fourth 82 feet. If now a particle thrown back by a rod of the innermost ring meets a rod of the second ring moving in the opposite direction, it will be thrown with a velocity of $62 - 52 = 10$ feet upon the third rod moving again in an opposite direction, and from the latter upon the fourth rod, and with a velocity of $72 - 10 = 62$ feet. From the last rod it finally leaves the machine with a velocity of $82 - 62 = 20$ feet, and is caught by the wooden frame.

By this repeated partial arrest of the velocities, the cohesion of the oil-cakes brought into the machine is overcome. The effect is extraordinary.

Fig. 169.



IMPROVED CENTRIFUGAL CAKE-BREAKER.

Fig. 169 shows an improved centrifugal cake-breaker for breaking the oil cake into small particles before it goes to the cake mill; it is manufactured by the Stillwell-Bierce & Smith-Vaile Co., of Dayton, Ohio.

COMPOSITION OF THE EXTRACTIVE FATS OF OIL-CAKES.

Oil-Cakes.	Cotton-seed.	Cocoanut.	Peanut.	Linseed.	Poppy-seed.	Palm-kernel.	Rape-seed.	Sesamé.	Sunflower seed.
Melting point	10° C.	23° C.	32° C.	Below 10° C.	21° C.	27° C.	Below 10° C.	26° C.	10° C.
Saponification number Mg. KOH.	194	244.4	190.4	194.4	186.3	249.2	178.9	193.0	195.0
Neutral fat	92.82 p. c.	81.14 p. c.	66.95 p. c.	89.56 p. c.	9.01 p. c.	83.79 p. c.	71.48 p. c.	23.18 p. c.	63.44 p. c.
Free fatty acids	3.24 p. c.	9.84 p. c.	86.96 p. c.	8.86 p. c.	71.01 p. c.	13.39 p. c.	13.47 p. c.	73.06 p. c.	29.84 p. c.
Total fatty acids, inclusive lecithin stearate	95.08 p. c.	86.78 p. c.	94.20 p. c.	94.31 p. c.	89.14 p. c.	93.93 p. c.	87.31 p. c.	94.24 p. c.	90.37 p. c.
Molecular weight of the fatty acids	273	207	280	270	277	217	302	280	273
Lecithin	4.35 p. c.	—	—	trace.	13.27 p. c.	—	6.99 p. c.	—	—
Lecithin stearate	3.06 p. c.	—	—	"	9.34 p. c.	—	4.92 p. c.	—	—
Phosphorus	0.166 p. c.	—	—	"	0.40 p. c.	—	0.268p. c.	—	—
Non-saponifiable fat (phytosterol).	1.11 p. c.	0.51 p. c.	1.47 p. c.	1.91 p. c.	1.51 p. c.	2.54 p. c.	3.29 p. c.	1.64 p. c.	1.79 p. c.

CONTENT OF FAT AND FREE FATTY ACIDS IN SOUND OIL-CAKES, ACCORDING TO NORDLINGER.

Variety of Oil-cake.		100 parts of oil-cake contain:		100 parts of total fat contain free fatty acids.
		Free fatty acids. I.	Total fat. II.	III.
Rape-seed	Minimum	0.72 parts.	7.67 parts.	8.39 parts.
	Maximum	1.02 "	9.70 "	13.23 "
	Mean	0.93 "	8.81 "	10.55 "
Poppy-seed	Minimum	3.72 "	8.92 "	43.70 "
	Maximum	6.86 "	10.34 "	70.70 "
	Mean	5.66 "	9.63 "	58.89 "
Peanut	Minimum	0.37 "	5.70 "	6.45 "
	Maximum	4.92 "	12.47 "	39.42 "
	Mean	1.42 "	7.65 "	18.62 "
Sesamé	Minimum	2.66 "	11.20 "	20.24 "
	Maximum	7.80 "	21.90 "	58.62 "
	Mean	6.15 "	15.44 "	40.29 "
Palm kernel	Minimum	0.62 "	8.00 "	6.28 "
	Maximum	3.16 "	14.70 "	26.21 "
	Mean	1.47 "	10.39 "	14.28 "
Palm kernel extracted		1.55 "	18.68 "	8.29 "
Cocoanut	Minimum	0.91 "	10.10 "	7.27 "
	Maximum	1.63 "	16.11 "	13.88 "
	Mean	1.31 "	13.11 "	10.51 "
Linseed	Minimum	0.43 "	6.82 "	4.00 "
	Maximum	1.06 "	10.80 "	15.50 "
	Mean	0.75 "	8.81 "	9.75 "
Castor	Minimum	0.68 "	4.80 "	8.33 "
	Maximum	1.74 "	8.17 "	28.72 "
	Mean	1.27 "	0.53 "	20.07 "

Oil cake as an addition to the feed and for fattening animals has proved valuable both in theory and practice.

All oleiferous seeds contain considerable quantity of nitrogenous substances (protein substance) which in regard to its composition and properties resembles the casein of milk.

The cake remaining in the press contains all this nitrogenous substance. But besides this substance so suitable for nutrition, oil-cake contains up to 10 per cent. fat substance which can be directly assimilated and contributes to the formation of fat. Finally oil-cake contains phosphates which serve for building up the skeleton.

Oil-cake is best fed by soaking in warm water and mixing with the other feed, such as grain, cabbage, potatoes, rutabagas, hay, bran, etc.

The appended table gives the average percentage of digestible constituents in oil-cake:

Names of oil-cake.	Protein substances.	Fat substances.	Non-nitrogenous substances.
Rape seed	85.5 p. c.	88.0 p. c.	78.0 p. c.
Linseed	87.0 "	91.0 "	91.0 "
Cotton seed	74.0 "	91.0 "	46.0 "
Sunflower seed	76.5 "	85.0 "	50.0 "
Palm kernel	98.0 "	98.0 "	94.0 "
Cocoanut	74.0 "	83.0 "	89.0 "

Taking the feeding value of hay = 100.
Rape seed cake has a feeding value = 190.
Linseed " " " = 220.
Poppy seed " " " = 140.
Palm kernel " " " = 250.

Feeding oil-cake exclusively gives meat of an inferior quality, oil-likefat, milk of a disagreeable taste, and very soft butter.

Hence oil-cake should be fed to a limited extent only, and its use entirely discontinued in the last stage of fattening, to prevent the meat of the animals from acquiring a foreign taste.

Independent of the importance of oil-cake as a nourishing substance, its composition and the large content of phosphoric acid in its ash prove it of great value as a manure. Regarding its use for the latter purpose, experience has shown that it should not be brought upon the field together with the seed, the germinating power of the latter being thereby frequently destroyed. This action of oil-cake may be explained by the fact that by its putrefaction, which under favorable conditions progresses very rapidly, a considerable quantity of ammonia is evolved, which, by presenting to the seed or young plants too great an abundance of nitrogenous nutriment, as well as by the direct influence of its alkalinity, exerts an injurious effect. The cause of the injurious action of oil-cake upon the seed was formerly attributed to the content of oil. It was held that the oil by enveloping the seed prevented the access of oxygen required for germination, and thus rendered the latter impossible. This is, however, not the case, the oil being too finely divided.

The oil-cake is either ground and applied to the soil like other fertilizers, or it is for some time macerated with water from the manure-pit, and the resulting fluid distributed over the field. The comminuted oil-cake may also be mixed with earth and subjected to initial putrefaction, whereby the loss of nitrogen by the volatilization of ammonia must, of course, be prevented.

For the determination of the content of fat in the oil-cake the same methods as for the determination of the content of oil in seed are used, p. 14.

To prevent moulding, which would render them unfit for feed, the oil-cakes when leaving the press must not be laid too close together, but sufficient space be left on all sides for the access of air. When thoroughly dry they will stand packing in any manner.

Oil-cake as well as oil-meal is frequently adulterated, such falsifications being best established by a microscopical examination. Particulars regarding methods of adulteration and their recognition will be given in speaking of the separate oil-seeds.

Oil-mill Plant.

The arrangement of an oil-mill, like that of every other factory requiring motive power, may be divided as follows:

1. The motive power.
2. The motor.
3. The working machinery (tools).
4. The connecting parts between the motor and machinery —the driving-gear, communication of movement.

To attain the most advantageous results, it has to be taken into consideration:

1. That nothing of the motive power is lost without being utilized;

2. That the motor renders the motive power available for use with the slightest unavoidable losses;

3. That the gearing absorbs as little power as possible, but

4. Transmits the greater portion of it to the machinery, care being taken to avoid losses there and to attain the most useful effect;

5. That the first-mentioned conditions be accomplished with the smallest expense possible.

Although wind or water present many advantages as motive power, for the regular, uninterrupted running of an oil mill steam-power alone is suitable, it being not dependent on metereological conditions. Where suitable water power is available, it may serve as an auxiliary power or as a reserve in case of a break-down.

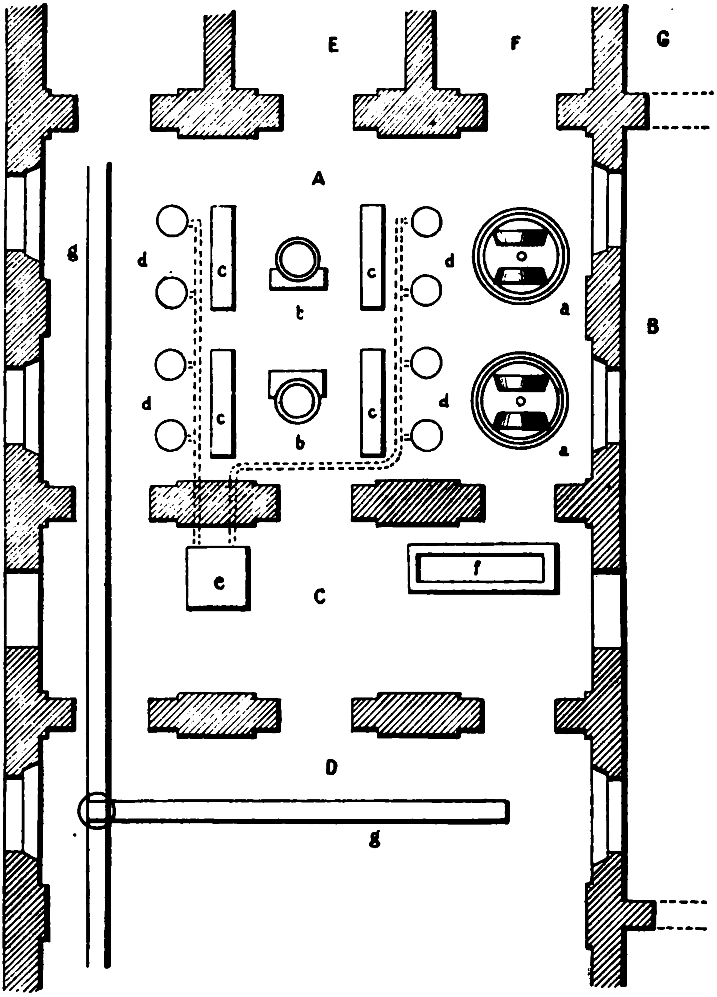
The choice of a suitable place for the establishment of an oil-mill is of prime importance. The site should be selected with reference to water and railroad facilities for the reception of supplies of seed, coal, etc., and for shipment of the finished products. The machinery required has been fully described in the foregoing pages, and it remains only to be mentioned that from the vessels standing under the presses the oil is generally collected in open tanks, in which it remains for a few days, when it is drawn off through a tap a few inches above the bottom and brought into barrels or larger reservoirs for the actual settling; this, settling, however, has nothing to dó with the refining to be described later on

It sometimes happens that the oil is much contaminated with seed-meal in consequence of torn press-cloths; in such a case the deposit in the tanks is mixed with the seed-meal previously to subjecting the latter to the first pressure; otherwise the deposit is brought into a special tank.

If the settling tanks are located beneath or alongside the mill the conduit and pump must be so arranged that the deposit is not stirred up either by the influx of fresh oil or by the operation of pumping. The deposit in the settling tank is from time to time removed and may be used in the manufacture of soft soap.

The ground plan of an oil-mill plant shown in Fig. 170 is sufficiently explained by the letters.

FIG. 170.

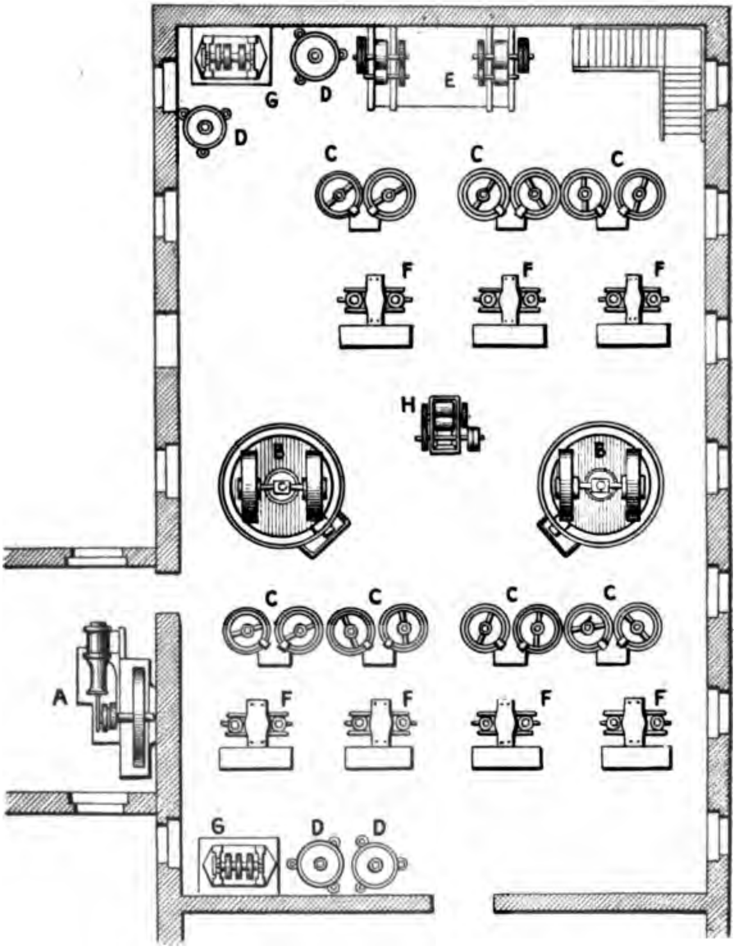


GROUND-PLAN OF AN OIL-MILL.

A, mill-room; *B*, boiler-house; *C*, engine-room; *D*, store-room for oil-cakes; *E*, office of foreman; *F*, shop of the machinist; *G*, repair-shop; *a*, two edge-runners; *b*, two heating-pans; *c*, four work-tables; *d*, eight presses; *e*, pumping machinery; *f*, steam-engine; *g*. railroad for the transport of oil-cakes.

Fig. 171 exhibits an oil-mill constructed by M. Ehrhardt. The plant has a crushing capacity of 26,000 lbs. of seed per day. The mill works with 2 crushing rolls, 3 presses for the first

FIG. 171.



OIL-MILL CONSTRUCTED BY M. EHRHARDT.

A, engine; *B*, 2 sets of edge-runners; *C*, 14 heating pans; *D*, 4 accumulators; *E*, 2 sets of crushing rolls; *F*, 3 presses for the first pressure and 4 presses for the second pressure; *G*, two sets of hydraulic pumps; *H*, 1 cake-breaker.

pressure, 1 oil-cake breaker, 2 sets of edge-runners, and 4 presses for the second pressure.

The cakes obtained by the first pressure are round and those by the second pressure 17.71 inches long, each cake weighing 2.112 kilogrammes (4.64 lbs.). To each press belong 2 heating pans. The building being but one story high, the crushing-rolls are placed in the mill-room.

As motor serves a steam-engine of 30 effective horse-power, with a cylinder diameter of 13.78 inches and a stroke of 22 inches. Besides the mill-machinery it drives a windlass, an elevator, and three oil-pumps.

CHAPTER XI.

MANNER OF OBTAINING FIXED OILS.

B. *By Extraction.*

A COMPLETE exhaustion of the seeds cannot be effected even with the greatest possible pressure, as the organic substances retain about 10 per cent., which has to be recovered by solvents. Jesse Fisher, of Birmingham, actually originated the modern use of carbon disulphide for this purpose, his first experiments dating from 1843. Besides carbon disulphide, other solvents can of course be used, especially the volatile petroleum ethers (benzine, canadol) introduced by Richardson, Vohl, and Hirzel.

1. *Extraction with Carbon Disulphide.*

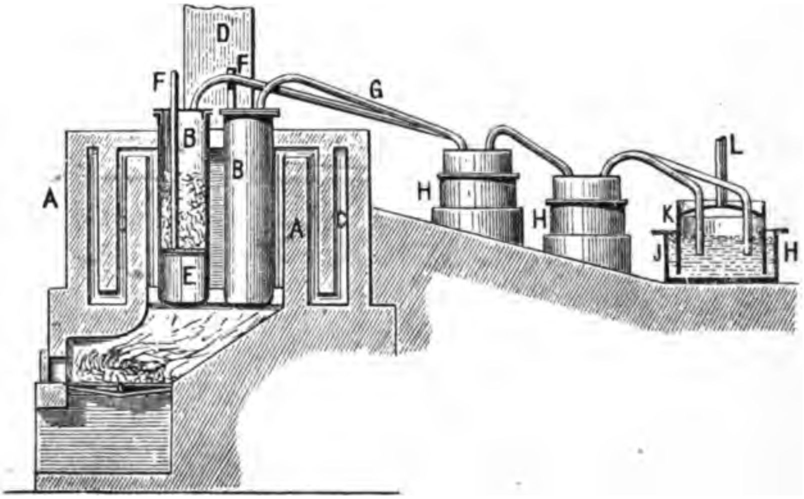
Carbon disulphide, CS_2, (consisting of 15.8 parts of carbon and 84.2 parts of sulphur) is still manufactured according to the method of the inventor Lampadius (1796), by conducting sulphur vapors over glowing coals.

The various apparatuses used in the manufacture, which is always conducted in the oil mill itself, are very much alike except that by Galy-Cazalet.

Fig. 172 illustrates Deiss's modern apparatus. It consists of the brick furnace *A* with four cast-iron retorts *B* entirely encircled by the fire. The smoke is conducted through the flues *C* into the chimney *D*. Each retort is provided, about one-third above the bottom, with a perforated clay-plate to separate the sulphur in the lower part of the retort from the charcoal or coke in the upper part. The sulphur is introduced through the pipe *F*, and the charcoal or coke through an opening in the lid. The sulphur, which quickly vaporizes by heating, combines with the glowing coal to carbon disulphide, the vapor being conducted through the pipe *G* into the condensers *H*. The latter consists of a water reservoir *J* and a bell *K*.

For the escape of the non-condensed vapors, etc., the pipe *L* is placed on the last condenser. These vapors being very noxious, as they contain carbonic oxide, carbonic acid, marsh gas, and large quantities of hydrogen sulphide, should not be allowed to escape into the open air, but be burned, and the vapors formed conducted over hurdles moistened with lime or caustic soda or into Laming's mass, a mixture of ferric hydrate with slaked lime and saw-dust.

FIG. 172.



APPARATUS FOR THE PREPARATION OF CARBON DISULPHIDE.

A, furnace; *B*, four retorts; *C*, flues; *D*, chimney; *E*, perforated clay plate; *F*, pipe for the introduction of sulphur; *G*, pipe for the sulphur vapor; *H*, condensers; *J*, water reservoir; *K*, bell; *L*, pipe for non-condensed vapor.

The coal used should be rich in carbon, and as free as possible from ash; charcoal and coke being the most suitable. It should be also poor in hydrogen and oxygen, as otherwise large quantities of the above-mentioned gases are formed.

The yield is greatest with a medium red heat; the loss of sulphur amounts to about 18 per cent., and that of carbon to about 50 per cent.

The operation is continuous, the sulphur wrapped in paper, being introduced about every 15 minutes through the pipe *F*. But, if fresh coal is to be put in, which is done every 6 to 10 hours, the introduction of sulphur is to be stopped at least one hour previously. After filling the retorts, the lids are again luted.

The emptying of the retorts from residues of coal and sulphur causes a considerable loss of material and time, and besides is very injurious to the workmen on account of the heat and the vapors from the burning carbon disulphide.

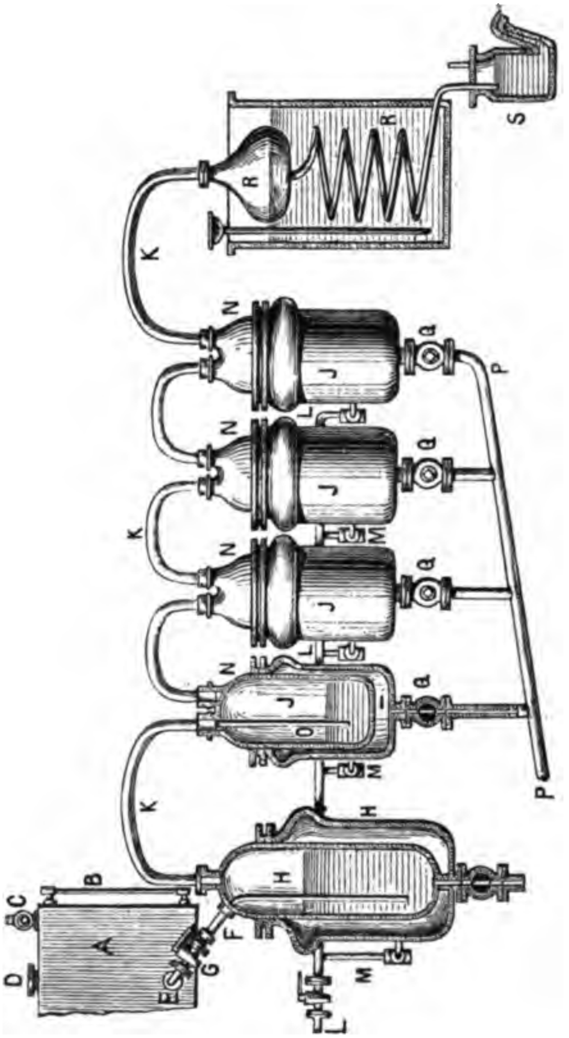
The product, crude carbon disulphide, obtained by the process, is contaminated by sulphur originating from non-fixed sulphur vapors, by hydrogen sulphide and combinations consisting of carbon, oxygen, and sulphur, which have not as yet been thoroughly examined.

As sulphur, which amounts to about 10 per cent., injures the dissolving powers of the carbon disulphide, and the other carbon combinations impart to it a disagreeable odor not characteristic of it, it has to be rectified.

Bonnière's apparatus, Fig. 173, is the most suitable for this purpose.

The carbon disulphide to be rectified is in the reservoir *A* provided with the stop-cock *C*, gauge-glass *B*, opening *D*, and discharge-pipe *E*. From here the carbon disulphide is conducted through the pipe *E*, provided with the cock *G* and the glass tube *F*, into the distilling apparatus *H*. The latter is successively connected by the pipes *K* with several smaller distilling apparatuses *J*. In the cover *N* are two openings in which the connecting pipes *K* are so fitted that the longer end of one connecting pipe, which is provided on the lower end with numerous small holes, reaches nearly to the bottom of the next distilling apparatus, while the shorter end serves as a discharge pipe of the preceding apparatus. After making connections with the cooling apparatus *R*, steam is introduced into the water-

FIG. 173.



RECTIFYING APPARATUS FOR CARBON DISULPHIDE.

A, disulphide carbon reservoir ; *B*, gauge glass ; *C*, stopcock ; *D*, opening ; *E*, pipe to the distilling apparatus ; *F*, glass tube ; *G*, cock on the pipe *E* ; *H*, large still ; *J*, small still ; *K*, connecting pipe ; *L*, steam pipe ; *M*, branches from *L* ; *N*, lids of the apparatus ; *O*, introduction pipe ; *P*, discharge pipe for water ; *Q*, discharge cocks ; *R*, cooling pipe ; *S*, receiver.

baths surrounding the distilling apparatus *H* and *J* through the pipe *L*, provided with branches and cocks *M*. The introduction of steam is regulated by the cocks according to the progress of vaporization and the temperature connected with it.

But, as complete purification is not possible even by repeated distillation, metallic solutions are placed in the stills for the absorption of foreign admixtures. Thus in the first apparatus *H* is placed concentrated potash lye for the absorption of sulphur ; in *J* solutions of lead, copper, and ferric oxides to fix hydrogen sulphite, olefiant gas, etc. After conducting the disulphide carbon through the varions metallic solutions, it is condensed under distilled water in a receiver resembling a Florence flask.

The loss in yield caused by purification amounts to as much as 25 per cent.

Pure carbon disulphide is a transparent, colorless liquid of great refractive and dispersive power, of a pure ethereal, chloroform-like odor, and a cooling spicy taste. It burns in the air with a blue flame, forming carbon dioxide and sulphur dioxide; and becomes explosive when its vapor is mixed with oxygen. Its specific gravity is 1.269 at 61° F., and its boiling point, under ordinary atmospheric pressure, at 115° F. It readily dissolves bromine, iodine, sulphur, phosphorus, fat oils, resins, many coloring substances, camphor, caoutchouc, gutta-percha, wax, paraffin, volatile oils, etc.

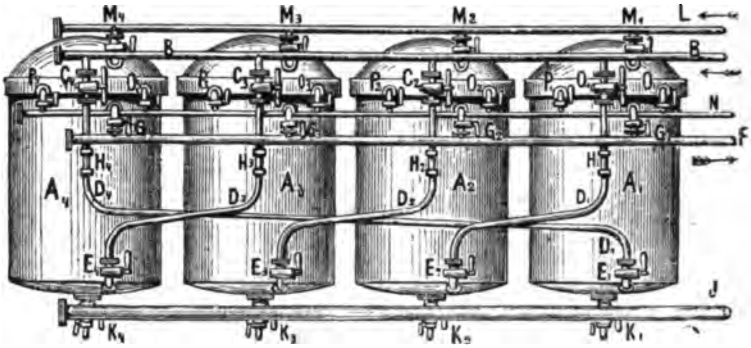
The apparatuses used in extracting the oil from the seed are nearly all alike as regards the principal operations. The seed prepared in the same manner as for expression, but dried, is placed in hermetically closed cylinders of various constructions.

Fig. 174 illustrates Heyl's apparatus. It consists of four or more cast-iron or sheet-iron cylinders, A_1 to A_4, communicating with each other and surrounded by steam jackets. The extracting vessels are so arranged that they can be emptied by tilting, which is rather inconvenient, as all the pipes have to be unscrewed.

In the cyclinders close above the bottoms is a perforated plate covered with fine wire gauze upon which the material to be extracted is placed. The cylinder is flilled to the top, and after placing a similar plate upon it, the upper opening is closed by a lid suspended to a crane. The cylinder as well as the lid is provided with a broad flange between which is placed a hemp tissue, firmly pressed together by 12 cramps, to serve as a packing.

After filling the cylinders with seed and arranging the packing, carbon disulphide is conducted from a resevoir through the principal pipe *B* to the extracting vessels, and is introduced into A_2 by opening the cock C_2 which communicates with the pipe *B*. The carbon disulphide passes through the bent pipe D_1, enters through the cock E_2 below the false bottom of the cylinder A_2, and after penetrating the mass and filling the cylinder, runs through the cock C_2 of the bent pipe *D*, and the cock E_3 into the cylinder A_3, reaching the fourth cylinder in

FIG. 174.



OIL EXTRACTING APPARATUS.

A_1 to A_4, four extracting cylinders; *B*, principal conduit for carbon disulphide; C_1 to C_4, cocks on the conduit; D_1 to D_4, conduits for carbon disulphide; E_1 to E_4, cocks on the pipes D_1 to D_4; *F*, discharge pipe for saturated carbon disulphide; G_1 to G_4, discharge cocks for saturated carbon disulphide; H_1 to H_4, glass tubes; *J*, discharge pipe for carbon disulphide; K_1 to K_4, discharge cocks; *L*, conduit for compressed air; M_1 to M_4, cocks for the introduction of air; *N*, steam-pipe; O_1 to O_4, steam-cocks on the jackets of the cylinders; P_1 to P_4, cocks on the cylinders themselves.

the same manner through the cock C_3, the pipe D_3, and the cock E_4. From the last cylinder it passes as a thoroughly saturated oil solution into a resevoir in which a vacuum has been created to promote the circulation of the fluid in the entire apparatus. After a quantity of oil solution corresponding to the contents of the cylinder A_4 has arrived, the cock G_4 is closed and the cock C_4 opened, whereby the cylinder A_4 is connected with A_1 by the bent pipe D_4 and the cock E_1.

After the exhaustion of the contents of the cylinder A_2, which is recognized by means of the glass tube H_2, placed on D_2 by the fluid running off being colorless, the cocks C_1 and E_2 are closed, and C_2 and E_3 opened, whereby the carbon disulphide runs into A_3, and from there to A_4 and A_1, A_2 being omitted. To effect this omission, and at the same time not to prevent the introduction of carbon disulphide, C_1, C_2, C_3, C_4 are so-called two-way cocks, which, when placed in one position, connect the principal pipe B with the branch pipes D, but interrupt a further flow through the principal pipe B, while in the other position they close the pipes D, and open the principal pipe B.

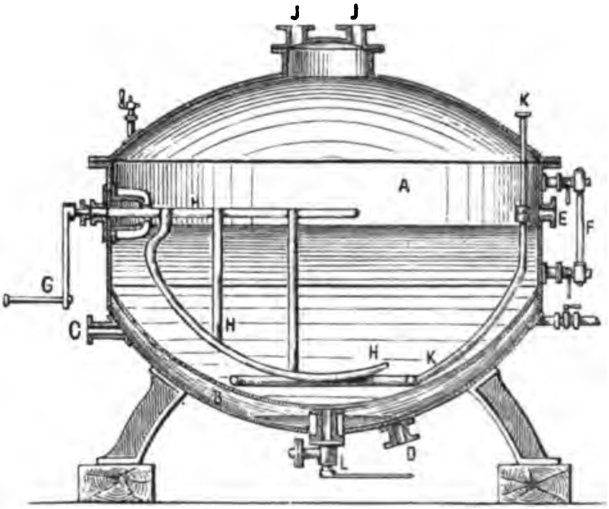
The cylinder A_2 is, however, still filled with carbon disulphide and material saturated with it. To remove the carbon disulphide the discharge cock K_2 on the bottom of the cylinder is opened, which communicates with the discharge pipe J, through which the carbon disulphide is conducted into a reservoir.

The discharge is promoted by opening the cock M_2, connected with the pipe L, and the admittance of compressed air, which displaces the liquid carbon disulphide. After the flow of the latter has ceased, the steam-cocks on the jacket O_2 and the cylinder P_2 are opened under constant admission of air and simultaneous introduction of steam through the pipe N into the upper part of the cylinder.

The carbon disulphide, converted into vapor by the heat, together with the steam, is, by the admission of air, conducted through the cock K_2, the pipe J, and a cooling pipe, placed between the extracting vessels and the reservoir, and collected in a reservoir to be re-used.

On account of the great volatility of carbon disulphide, considerable loss would, however, be incurred by the above mentioned admission of air. To avoid this, the reservoir serving for the reception of the condensed carbon disulphide and steam is closed and connected by a pipe with a long, narrow, horizontal cylinder half filled with oil and provided with a fan shaft. The vapors of carbon disulphide entering the cylinder from the reservoir are absorbed, together with the air, by the oil, the surface of which is constantly agitated by the fan shaft, while the air, rendered entirely inodorous, passes out at the other end. The carbon disulphide is finally separated from the oil by distillation, and again used.

FIG. 175.



DISTILLING APPARATUS.

A, still; *B*, jacket; *C*, steam-pipe; *D*, discharge-pipe for condensed water; *E*, pipe for the introduction of the oil solution; *F*, gauge; *G*, crank; *H*, stirrer; *J*, escape for vapors of carbon disulphide; *K*, circular pipe; *L*, discharge for the oil.

After the cylinder A_2 is sufficiently steamed it is emptied and again charged with seed and connected with the cylinder A_1, while the other cylinders undergo the same manipulation described above.

The saturated oil solution is subjected to distillation, which can be readily effected in Heyl's apparatus, Fig. 175.

The lower part of the still *A* of boiler plate is surrounded by the steam-jacket *B*, into which steam is admitted through *C* and the condensed water discharged through *D*.

The concentrated oil solution runs from a reservoir standing at a higher level through the pipe *E* into the still, the admission of a sufficient quantity being indicated by the gauge *F*.

The carbon disulphide brought to the boiling point (114° F.) by the steam introduced into the jacket, vaporizes quickly, vaporization being still more accelerated by revolving the stirrer *H* by means of the crank *G*.

The vapors of carbon disulphide escape through four openings in the upper part of the still into a capacious coil, the lower part of which enters, under water, a reservoir.

Notwithstanding the volatility of carbon disulphide, the oil retains a portion of it so tenaciously that a complete separation cannot be accomplished by the introduction of steam into the jacket *B*; steam must therefore be introduced into the oil itself. This is done by means of the pipe *K*, the lower end of which is perforated. After making the connection with the steam-pipe, the steam is forced in fine jets through the oil, effecting complete vaporization of the carbon disulphide. After completed distillation the oil is discharged through *L*.

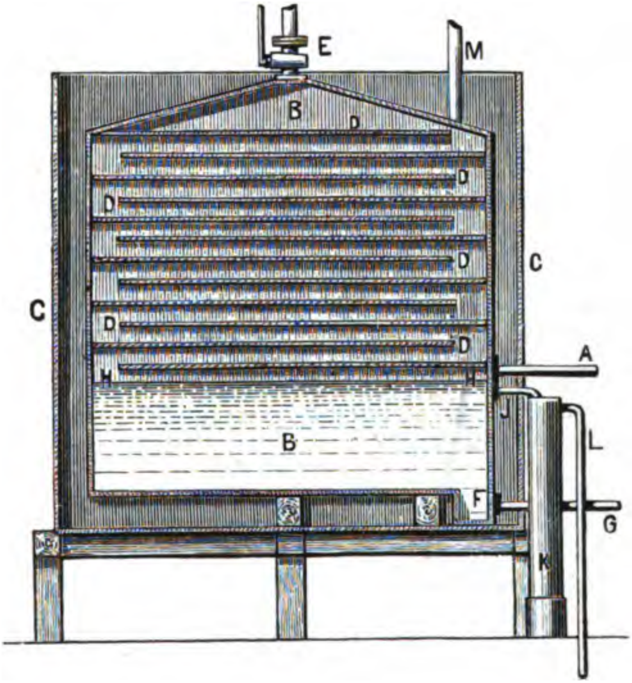
The oil is then freed from the coloring substances extracted by the carbon disulphide by treating it with zinc chloride (1½ parts of zinc chloride to 100 parts of oil).

The difficult condensation of the vapors of carbon disulphide has been overcome by the suitable construction of Seyferth's condenser, Fig. 176.

The vapors pass from the still through the pipe *A* into the lower part of the large condensing box *B*, placed under the water reservoir *C*.

The upper portion of the box is provided with compartments, upon which lie perforated metal plates in such a manner that they are alternately open on both sides, and the steam has to pass through the apparatus by as long a route as possible. To furnish a large cooling surface to the current of steam, cotton threads, or some other fibrous substance, are drawn through the holes in the metal plates. The cooling water, entering through the cock *E* and falling upon the upper plate, trickles down the threads upon the second plate, and so on into the lower part of the box until its level is at *H*.

FIG. 176.



CONDENSING APPARATUS FOR CARBON DISULPHIDE.

A, pipe for vapor of carbon disulphide; *B*, condensing box; *C*, water reservoir; *D*, perforated metal plates; *E*, cock for admitting cooling water; *F*, collecting place for the condensed carbon disulphide; *G*, discharge-pipe for carbon disulphide; *H*, level of water; *J*, discharge-pipe for the water; *K*, sheet-iron cylinder; *L*, discharge-pipes; *M*, air-pipe.

The cooling surface of the apparatus is, therefore, the total of the surface of all inner metallic parts, augmented by the total surface of the threads. The cooling is considerable and more complete than by coils, and is still further augmented by the team moving in a direction opposite to that of sthe water.

The condensed carbon disulphide separates from the water by gravity and collects in the depression *F* in the box *B*, from whence it passes into a reservoir, or at once through the pipe *G* into the extracting vessels.

When the water has reached the level *H*, that added by condensation runs off through the pipe at *H*, which reaches nearly to the bottom of the sheet-iron cylinder *K*, and from there further through the pipe *L*. Upon the surface of the cooling water floats a small portion of carbon disulphide carried by small steam bubbles. By the ascending and descending motion in the cylinder *B*, these bubbles, however, burst, and the carbon disulphide falls to the bottom and is temporarily poured into the reservoir for the condensing water.

The pipe *M* serves only the purpose of making connection with the outer air. With complete condensation nothing is lost, though tc avoid any possible loss a small condenser may be placed on the pipe *K*.

Roth's apparatus for extraction, distillation, and condensation are represented by Figs. 177 to 181.

The carbon disulphide, before being conducted to the extractor, is in a so-called sulphur vat connected with an auxiliary reservoir. Both the sulphur vat and the auxiliary reservoir are in a brick basin lined with cement, and are constantly kept under water to prevent any development of gas from the carbon disulphide at an ordinary temperature.

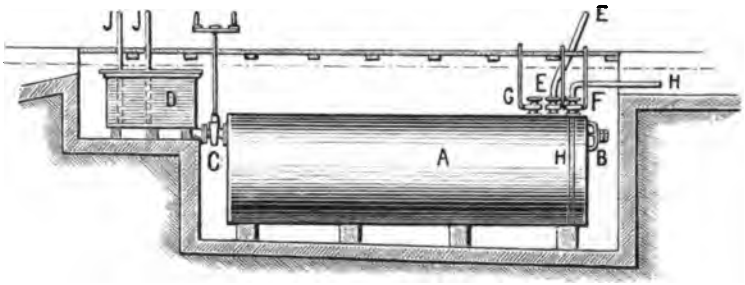
The sulphur vat consists of a cylindrical sheet-iron boiler *A*, with two man-holes *B* for cleansing, which is required about every two years. The cock *C* connects the boiler *A* with the auxiliary reservoir *D*, and also disconnects them with the distilling apparatus at work.

The cock *E* connects the sulphur vat with a water reservoir placed about 20 feet above the floor. The column of water pressing upon the carbon disulphide forces it through the pipe

H and the cock *F* into the pipe leading to the extractors. This pipe lies under water in a brick channel, branches provided with cocks leading from it to the separate extractors.

The cock *G* serves for the discharge of the water which is spontaneously forced through it by the greater gravity of the carbon disulphide coming from the auxiliary reservoir. The cock *G* is also used for measuring the quantity of carbon disulphide in *A*. For this purpose a small iron rod coated with lard is introduced into *A*, through the cock *G*, and allowed to remain a short time. On removing the rod the depth of carbon disulphide in *A* is indicated by the extent to which the lard is dissolved. This is measured and the quantity of carbon disulphide in *A* calculated from tables.

FIG. 177.



SULPHUR VAT.

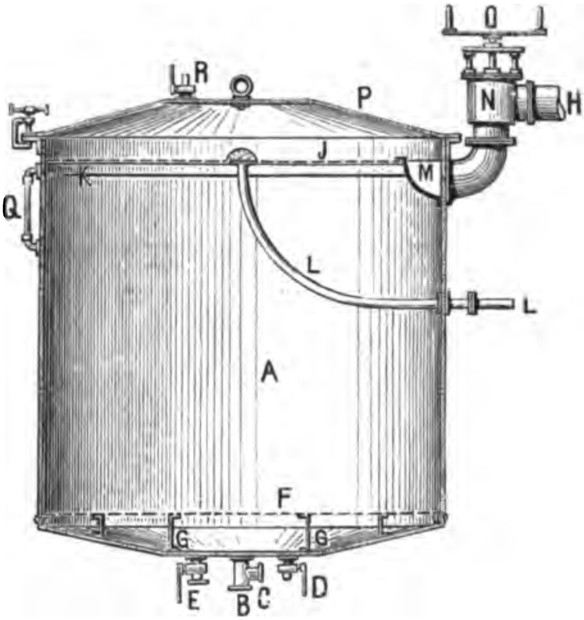
A, sheet-iron cylinder; *B*, two man-holes; *C*, cock in the pipes between *A* and the auxiliary reservoir *D*: *E*, pipe and cock between *A* and the water reservoir; F, pipe and cock between *A* and the extractors: *G*, discharge-cock for water; *H*, pipe leading to the extractors; *J*, pipes for condensed carbon disulphide.

The pipes *J* form the conduits for the condensed carbon disulphide coming from the condensing apparatus. All the conduits are about 3 inches in diameter. The boiler *A* is about 20 feet long, with a diameter of 6 feet.

The carbon disulphide is slowly conducted from the sulphur vat, in which it is stored, from below into the extractors, the cross section of one of which is shown in Fig. 178.

The extractor consists of a sheet-iron cylinder *A* resting upon columns. The T piece screwed and riveted to the bottom leads with the pipe *B* to the sulphur vat, and with the pipe *C* to the steam-boiler. The cock *D* serves for the discharge of condensed water, while the cock *E* opens or closes communication with a second extractor. In the cylinder *A* is a perforated bottom resting upon the supports *G* and covered with sackcloth. Seven and one-half feet above *F* is another perforated bottom, also covered with sackcloth and resting upon the supports *K*. The space between both is filled with material, the sackcloth answering the purpose of a filter.

FIG. 178.



OIL EXTRACTOR.

A, cylinder; *B*, pipe for the introduction of carbon disulphide; *C*, pipe for the introduction of steam; *D*, discharge-cock for condensed water; *E*, cock and conduit to the second extractor; *F*, perforated bottom; *G*, supports; *H*, pipe to the condensing apparatus; *J*, perforated bottom; *K*, supports; *L*, pipe to the still; *M*, collecting basin; *N*, valve; *O*, crank; *P*, lid; *Q*, glass gauge; *R*, air-cock.

The bent pipe *L*, provided on the upper end with a strainer, conducts the concentrated oil solution from the upper bottom *J* to the distilling apparatus.

A collecting basin *M* forms the connection between the extractor *A*, the valve *N*, and the pipe *H*, the latter conducting the carbon disulphide vapors to the condenser.

The valve *N* has a diameter of about 12 inches, and can be quickly opened and closed by the lever *O*.

The gauge *Q* shows the level of the carbon disulphide and allows of samples being taken.

The lid *P* is fastened to *A* by screw clamps and packing of hemp hose, so that it can be quickly removed.

By the introduction of fresh carbon disulphide from below, the concentrated oil solution is forced into the distilling apparatus, the introduction of fresh carbon disulphide being continued until a sample taken at *Q* shows the presence of pure carbon disulphide. One-half of the latter is then conducted through the cock *E* into a second extractor, while the other half is allowed to run quickly back into the sulphur vat.

After the discharge of the carbon disulphide, all the communications are closed with the exception of the conduit to the second extractor, and steam admitted from below through *C*. This heats the seed and distils off the carbon disulphide adhering to it.

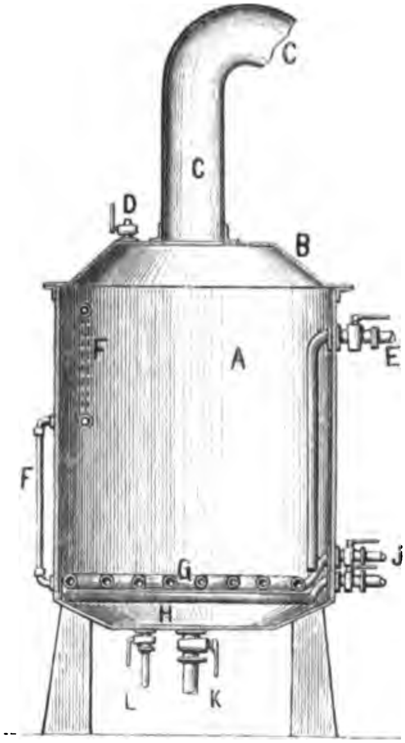
After being convinced by a sample that the mass is entirely free from carbon disulphide, it is removed from the extractor. The purpose of the cock *F* is to allow the excess of steam to escape after distilling off the carbon disulphide.

After completed distillation the lid *P* is taken off by means of a tackle, the mass removed, the extractor again charged, and the operation commenced anew.

Fig. 179 shows the construction of the distilling apparatus. It consists of a sheet-iron cylinder *A*, with a helmet screwed upon it, and the lid *B* provided with a man-hole. In the centre of the lid *B* is a pipe *C* about 16 inches in diameter, through which the carbon disulphide vapors are conducted to the condenser. There is also the cock *D* for the discharge of steam after completed distillation.

Through the cock *E* the oil solution is introduced into the still and rises to half its height, as can be seen by the gauge *F*.

FIG. 179.



DISTILLING APPARATUS.

A, sheet-iron cylinder; *B*, lid; *C*, pipe to the condenser; *D*, air-cock; *E*, pipe and cock for the introduction of the oil solution; *F*, glass gauge; *G*, upper steam coil; *H*, lower steam-coil; *J*, steam-cock; *K*, discharge-cock for oil; *L*, discharge-cock for condensed water.

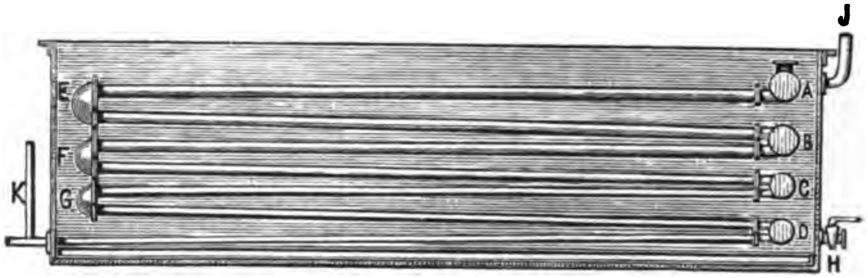
On the bottom lie two steam-coils, *G* and *H*, the upper one, *G*, being entirely closed, while the lower one, *H*, is perforated by over 200 small holes.

By the introduction of steam through the cock *J*, the oil solution is slowly heated and the carbon disulphide distilled off.

The lower perforated steam-pipe is only used to remove the last traces of carbon disulphide from the oil and the still with all the energy of live steam.

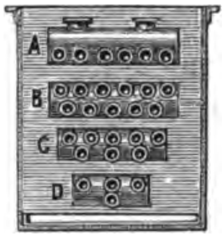
After completing the operation, the oil together with the condensed water is discharged through the cock *K* into a reservoir, where it remains for four hours for the oil to separate from the water.

FIG. 180.



CONDENSING APPARATUS. LONGITUDINAL SECTION.

FIG. 181.



CONDENSING APPARATUS. CROSS SECTION.

A, *B*, *C*, *D*, pipe distributors; *E*, *F*, *G*, curved joints; *H*, pipe for the cooling water; *J*, discharge-pipe for heated water; *K*, rising pipe to the safety-box.

The condensed water formed in the closed steam-coil is discharged through the cock *L*.

Figs. 180 and 181 show the cooling or condensing apparatuses. Their arrangement is very good, as in the construction of a condenser care should be taken to obtain as large a condensing surface as possible in the smallest space.

The spirals lie in a box and lead from an upper cast-iron distributor *A*, first in six pipes, each about 16½ feet long and 3½ inches in diameter, to the curved cast-iron joint *E*, and from here in six pipes, each 3½ inches in diameter, to the second distributor *B*. From the latter five pipes, each about 3 inches in diameter, lead to the curved joint *F*, and then back to the distributor *C*; from here three pipes, each about 2½ inches in diameter, lead to the curved joint *G* and back to the distributor *D*. From the latter a pipe, about 2⅞ inches in diameter, conducts the condensed carbon disulphide back to the auxiliary reservoir (Fig 177).

The pipes are arranged in a cast-iron box or a brick basin lined with cement.

The cooling water is introduced from below through the cock *H*, and the heated water discharged above through the pipe *J*.

To effect complete condensation of the vapors, the rising pipe *K* is placed on the lowest pipe. It enters, under water, a lead box placed at a higher level, where the remaining vapor is condensed. This so-called safety-box is also provided with a cock for the escape of air from the condenser.

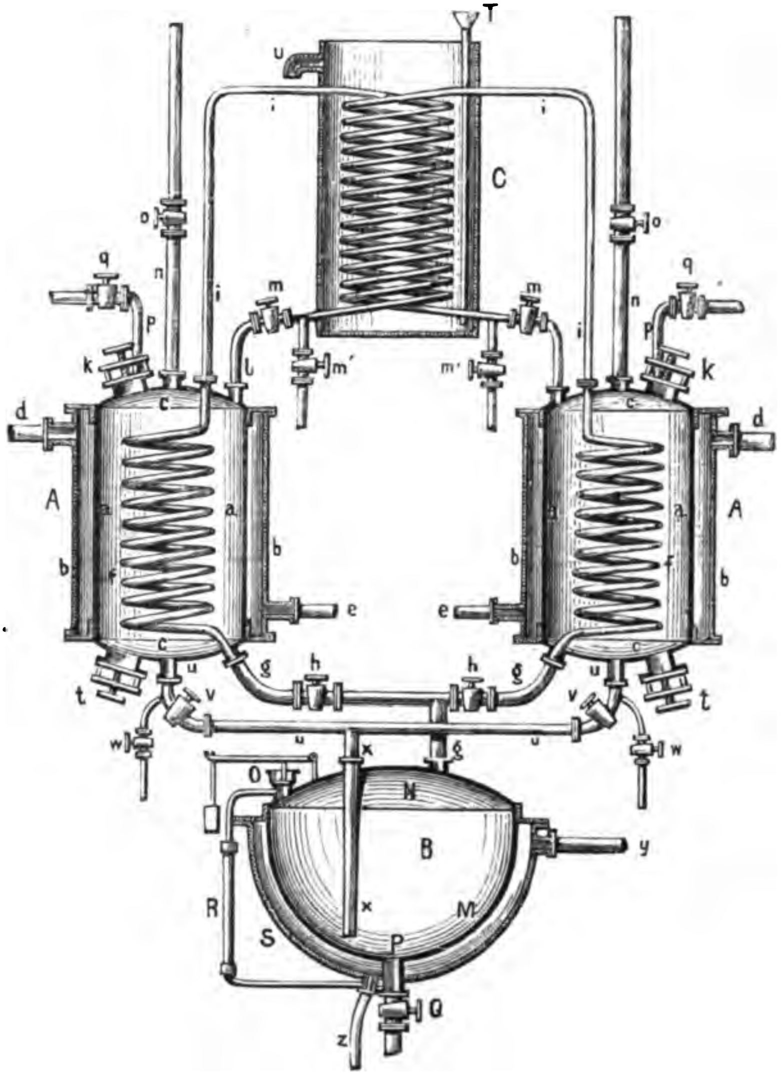
2. *Extraction with Canadol.*

Canadol is the term applied by H. Vohl to that portion of the volatile hydrocarbons of Pennsylvania petroleum which boils at 140° F., and has a specific gravity of 0.650 to 0.700.

For extracting the oil from oleiferous seed by means of canadol, Vohl has constructed the apparatus shown in Fig. 182. It consists of three principal parts, viz., the two extractors *AA*, the collecting and boiling vessel *B*, and the condenser *C*.

The extractors consists of copper cylinders, *a a*, tinned inside and provided with curved lids and bottoms, *c c*, of the same material. These copper cylinders are surrounded by sheet-iron jackets *b b*, the empty space between the latter and the cylinders serving for the reception of hot water or steam introduced

FIG. 182.



VOHL'S APPARATUS FOR EXTRACTING WITH CANADOL.

A, extractors; *B*, collecting and boiling vessel; *C*, condensing vessel; *M*, inner vessel of the boiling vessel *B*; *N*, lid; *O*, valve; *P*, discharge-pipe; *Q*, cock on discharge-pipe; *R*, gauge; *S*, outer vessel of boiling vessel; *T*, inlet pipe for cold water; *U*, discharge-pipe for cold water; *a a*, cylinder; *b b*, jacket; *c c*, curved bottoms; *d d*, inlet pipes; *e e*, discharge pipes; *f f*, coils connected by the pipes *g g* with boiling vessel *B*; *h h*, cocks on those pipes; *i i*, pipes in connection with the condensing vessel *C*; *k k*, charging holes; *l l*, *n n*, *p p*, pipes in the lid; *m m*, *o o*, *q q*, cocks on those pipes; *r*, manometer; *s*, valve; *t t*, apertures in the bottom, and *u u*, pipes with cocks *v v*, *w w*; *x*, *y*, *z*, pipes on the boiling vessel *B*.

through the pipes *d d*. The water, as well as the condensed water, is discharged through the pipes *e e*.

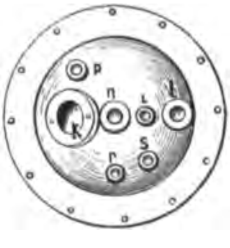
The interior of the two copper cylinders is provided with coils *f f*, tinned inside and out, which, on the lower bottoms, are connected by the pipes *g g* with the collecting and boiling vessel *B*; the connection can be interrupted by closing the cocks *h h*.

The upper ends of the coils pass into the pipes *i i*, whereby they are connected with the condensing vessel *C*.

The upper curved lids of the extractors have charging holes *k k* provided with well-fitting tinned copper lids which can be tightly closed by set-screws, As a further security, the outer edges of the lids are provided with a cork lining or a ring of pure moist hemp. Minium or lead rings cannot be used, as they would contaminate the oil, and rubber rings would dissolve.

The lids receive besides the pipes *l l* with the cocks *m m* and *m′ m′*, the pipes *n n* with the cocks *o o*, and the pipes *p p* with the cocks *q q*. They are further fitted with the manometer *r* and the valve *s* (Fig. 183, upper view of the extractor).

FIG. 183.



The bottoms of the extractors are provided with wide openings, *t t*, exactly like the charging holes *k k*, and closed in the same manner.

There are besides on the lowest point the pipes *u u* provided with the cocks *v v* and *w w*. These two pipes enter the joint pipe *x x*, whereby they are connected with the collecting and boiling vessel *B*.

The collecting and boiling vessel *B* consists of two semi-spherical vessels, the inner smaller one *M* being made of copper, tinned inside. The curved lid *N*, also of tinned copper, receives the pipes *x* and *y*, the first reaching to within one inch of the bottom, and the latter only into the dome. The lid is further provided with the valve *O*.

On the lowest point of the inner vessel *M* is the discharge-pipe *P*, with the cock *Q*, the portion of the pipe above the cock being connected with the gauge *R*.

The outer semi-spherical vessel *S* consists of cast iron, and is provided with the pipes *y* and *z*, the first serving for the introduction of steam and the latter for the discharge of condensed water.

The condensing vessel *C* consists of sheet-iron and contains two tinned copper coils, each being connected with the corresponding extractor by the pipes *i* and *e*.

The pipe *T* serves for the introduction of cold, and *U* for the discharge of hot, water.

To operate the apparatus, the aperture *t* in the extractor *A* is opened and about two-thirds of the surface of the bottom covered with a felt disk about one-eighth inch thick, which is provided in the centre with a felt cork formed by stitching small felt disks together, so that it can be conveniently introduced into the pipe *u*. This cork must not fit too tight, as it would stop the discharge, making it finally impossible, and besides, the density and thickness of the felt depend on the substance to be extracted.

The aperture *t* is then closed and the ground substance to be extracted introduced through the charging hole *k*. The mass is uniformly distributed in the extractor without compressing it to any extent, and a felt disk, provided with a hole for the pipe *i*, placed on top. The charging hole is then carefully closed.

During this operation the cocks *o*, *q*, *w*, and *Q* are closed and *m*, *m′*, *o*, and *h* open.

By opening the cock *o* on the pipe *n*, which is connected with the reservoir containing the canadol, the latter flows into the extractor and is uniformly distributed by the top felt disk.

The air in the apparatus escapes through the pipe *l* and the cocks *m*, *m'*.

The solvent, impregnated with oil, passes through the pipe *m*, the cock *v*, and the pipes *x x* into the collecting or boiling vessel *B*.

The air displaced in the latter escapes through the pipe *g*, the cock *h*, the coils *f f*, the pipes *i i*, and finally reaches the open air through the cock *m'*.

After the admittance of sufficient solvent, and when *M* is about two-thirds full, which is recognized by the gauge *R*, *o* is closed, and the contents of *M* brought to the boiling point by injecting a slight jet of steam through the pipe *g*.

x x being closed by the liquid, the vapors of the solvent escape through the pipe *g* and pass into the coils *f f*, where they are completely condensed and then run back to *B*. After the contents of the extractor *A* are heated and have finally reached the boiling point of the solvent, the vapors are condensed in the condenser *C*, which they reach through the pipes *i i*. As soon as any of the solvent runs off through the cock *m'*, the latter is closed. The condensed solvent then returns to the extractor. In this manner the seed-meal is extracted by a comparatively small quantity of solvent.

To see whether the meal is completely exhausted, the cock *v* is closed and a sample taken by means of the test-cock *w*. If the sample leaves an oil stain upon paper, extraction is not finished; but if the reverse be the case the cock *M* is closed, so that no more canadol is admitted to the meal, but runs off through the cock *m*.

Steam is now introduced into the jacket *b* through the pipe *d*, whereby the contents are heated to a higher degree and the developed canadol vapors exert a considerable pressure upon the surface of the meal residue. The greater portion of the solvent absorbed by the meal is forced downwards and passes through the pipe *w*, the cock *v*, and the pipes *x x* into the collecting or boiling vessel *B*.

During this operation special care must be taken to observe the level in *M*. It must be remembered that the extractor being two-thirds filled, the contents expand by heating, and now that nearly the entire quantity of solvent retained by the seed residue is added, an overflow of the fluid in *B* into the coils *f f*, and finally into the condenser, might occur, which would cause considerable loss.

If the level in the boiling vessel *B* rises too high, the introduction of steam into the extractor *M* must be at once stopped and the cock *q* on the pipe *p* slowly opened.

After the operation of separating the canadol from the meal residue is finished, which is recognized by the decrease of the level in *B*, *q* is opened and *v* closed.

The pipe *p* is connected with a cooling apparatus and the latter with an exhauster, whereby the developed canadol vapors are energetically absorbed from the meal residue, and, passing through the cooling apparatus, condensed.

In this manner the seed residue is quickly converted into a dry powder, and with a well-conducted operation retains scarcely a slight odor of canadol.

By opening the cock *Q*, the pipes of which are connected with a blow-off pipe, the contents of the vessel *B* are discharged and freed from canadol by the injection of steam. The oil is then dephlegmated by common salt or weathered Glauber's salt.

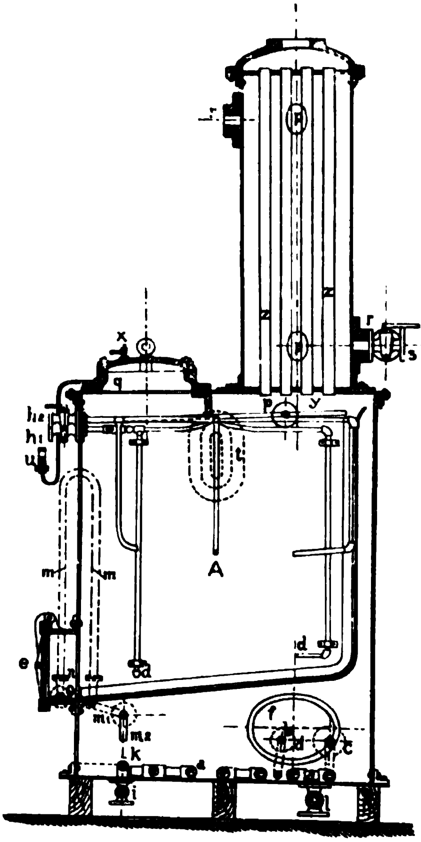
3. *Extraction with Benzine.*

Figs. 184 to 187 exhibit *Merz's universal extractor*, which is much used for the extraction of oil from seed.

Extraction commences at an ordinary temperature; the contents of the extractor become gradually heated, partially by the gases enveloping them and partially by the refluent, directly condensed, warm solvent, the temperature of the latter finally rising to the boiling point. With increasing temperature the action of the solvent becomes of course more effective, the last portions of the contents of the extractor being readily extracted at the boiling temperature.

The apparatus consists essentially of two parts, viz., the extractor *A* and condenser with reservoir *B* which are connected above by a pipe.

Fig. 184.

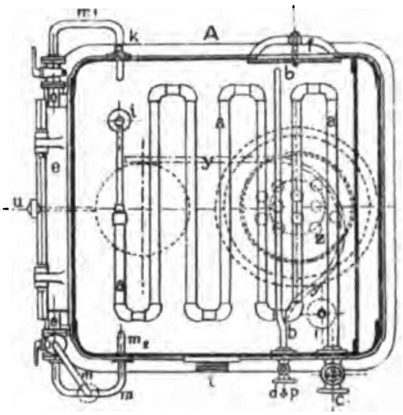


Longitudinal Section.

MERZ'S UNIVERSAL EXTRACTOR.

The extractor *A* being charged through the man-hole *q*, the cover is hermetically closed, and benzine introduced through the cock *p* from the reservoir *B*. The siphon pipe *m m* immediately draws the fluid to the lower part, where it is heated by the coil *A*. The benzine vapors evolved ascend between the walls,

FIG. 185.

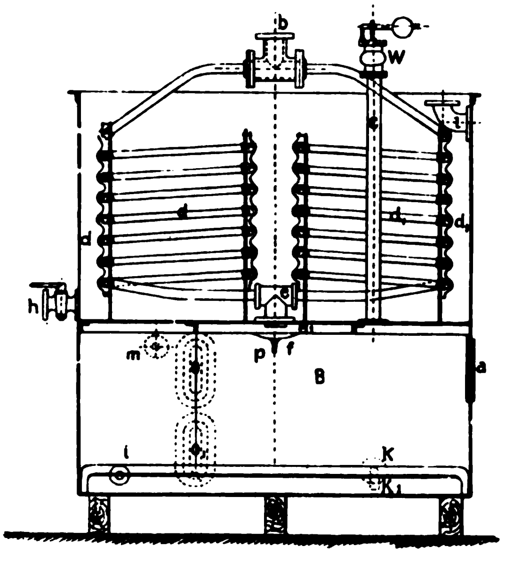


Ground-plan.

MERZ'S UNIVERSAL EXTRACTOR.

A, extractor; *P*, reflux-pipe; *a*, heating coil; *b*, pipe for introduction of steam; *c*, valve; *d*, nozzle-pipe; *e*, man-hole; *f*, fire-place; *h*, cocks; *i*, discharge-cock; *k*, connecting piece; *l*, discharge-cock; *m m*, siphon-pipe: *n*, cock; *o*, test-cock; *p*, inlet-cock; *q*, man-hole; *r*, discharge-cock; *s*, three-way cock; *u*, manometer; *x*, cock; *z*, cooling-pipes.

FIG. 186.

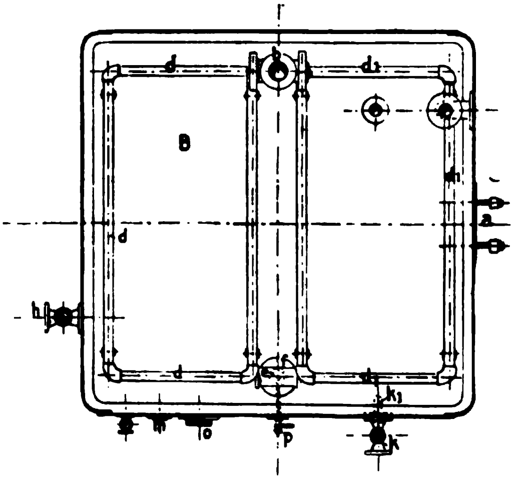


Longitudinal Section.

MERZ'S UNIVERSAL EXTRACTOR.

heating thereby the contents of *A*, and enter the pipe *z z* of the reflux-condenser, where they are condensed. The warm product of condensation falls back into *A*, and when it reaches the level of *m* is again drawn by the siphon to the lower part, where the benzine is again vaporized, then condensed in *z z*, etc., the same circuit being repeated until a sample taken at *o* shows no more extract, when extraction is finished. The cooling water is then discharged from the reflux-condenser by turning the three-way cock *s*, and the benzine-vapors are no longer condensed in the reflux-condenser, but ascend directly to the condenser *B*, where they condense and collect in the lower portion of *B*. To accelerate distillation, steam is introduced through *b* and *d*, until the steam issuing from the cock *x* no longer

FIG. 187.



Ground Plan.

MERZ'S UNIVERSAL EXTRACTOR.

B, condenser; *a*, man-hole; *b*, T-piece for connection with *P*, Fig. 184; *c*, air-pipe; *d*, coils; *e*, connecting piece; *F*, intercepting basin; *h*, influx of cooling water; *i*, discharge-cock for benzine; *k*, discharge-cock; *l*, outlet for cooling water; *m*, cock; *o*, looking-holes; *p*, test-cock; *w*, valve of air-pipe.

smells of benzine, and a sample of the condensed product coming from the cooler taken by means of the cock *p*, proves to be pure water without a film of benzine.

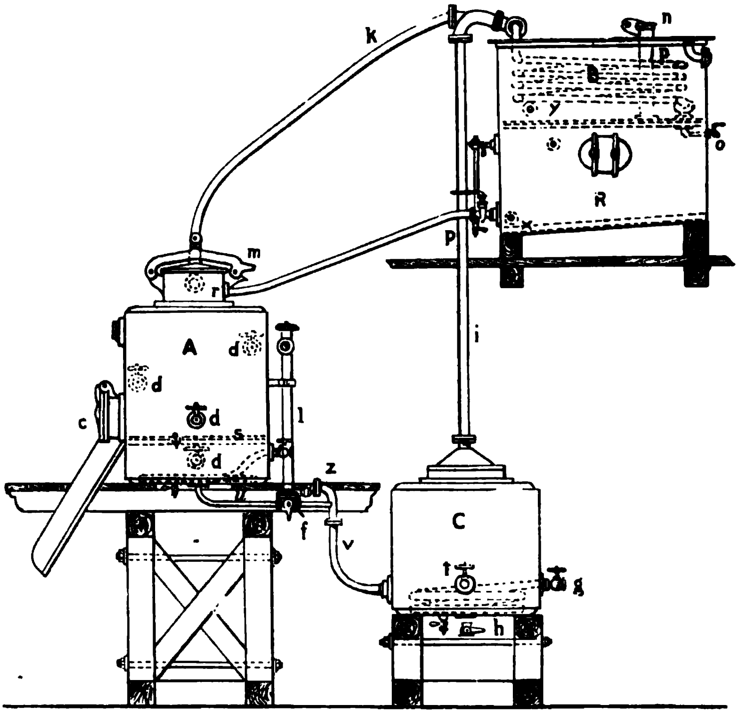
The apparatus may be operated intermittingly, as described, or continuously; in the latter case the escape of the oil-solution is so regulated that the level of the fluid is maintained constant by the vaporized and regenerated solvent. In both cases an almost uninterrupted circulation of the solvent is effected; the contents of *A* are gradually heated by the vapors ascending from the lower part, and the concentrated fat solution running off is replaced by pure, almost boiling benzine, all conditions required for intense and rapid extraction being thus fulfilled. The vapors having an opportunity of expanding, no pressure takes place in the apparatus; and the cooling arrangements being very suitable, no gas can escape, the loss of benzine being at the utmost 1 per cent.

Fig. 188 exhibits an extracting apparatus constructed by Wegelin & Hübner of Halle, Germany.

The solvent is brought through the pipe *p* into the reservoir *R*, forming the lower part of the cooler *B*. The apparatus *A*, having been charged through the man-hole *m* with the mass to be extracted, a perforated plate is placed in position at *r*, and the man-hole closed. The cooling water is brought into *B* by opening the cock *y*. The three-way-cock *f* is so fixed as to establish communication between the pipe *l* and the apparatus *A*. The cock *q* is then opened and the solvent penetrates from above in the apparatus, and in passing down becomes more and more saturated with oil. It next goes through the sieve *s*, through the pipe *u*, the three-way cock *l* and pipe *r* to the collecting vessel *C*. By opening the valve *g*, steam is admitted to the heating coil in the collecting vessel, whereby the solvent is vaporized, the vapors ascending to the cooler *B*, where they are condensed, the product of condensation passing into the reservoir *B*, and from there again through the cock *q* into the reservoir *A*. The apparatus *A*, as well as the pipes *i* and *k* are enveloped in non-conductive material to prevent loss of heat. The extracting process in *A* is controlled by taking samples from the test-cock *s*.

The expulsion and regaining of the solvent from, the exhausted material in *A* is effected as follows: The cock *q* is first closed. The three-way cock *f* is then so fixed as to establish direct communication between the apparatus *A* and the apparatus C, the pipe *l* being also disengaged. All the solvent in *A* now runs into *C*, where it is distilled off, the oil remaining behind. By opening the valves *d* steam is blown into the exhausted mass in *A*, whereby the solvent is driven off and passes in the form of vapor through the pipes *k* into the

FIG. 188.



WEGELIN & HUBNER'S EXTRACTING APPARATUS.

cooler *B*, where the vapors are condensed, the product of condensation collecting in *R*. To expel the last traces of solvent from the extracted fat or oil, steam is blown into the apparatus *C* by opening the valve *t*. Besides the solvent, steam also reaches *B* and collects in *R* as water beneath the solvent.

By taking samples from the test-cock *o*, the time when steaming the exhausted mass in *A* or the fat or oil in *C* may be considered finished, is recognized. A gauge indicates the level of the solvent and of the water in the reservoir. The apparatus *A* is emptied by means of a man-hole *e*, while the oil in *C* is discharged through the cock *h*; *p* is a stand-pipe upon the reservoir *R*, and is closed by a valve *n* to prevent vaporization of the solvent. The apparatus throughout works without pressure, thus excluding all danger of over-charging.

Braun prefers ether to benzine for the following reasons: Benzine consists of a number of hydrocarbons of different boiling points, even the best quality of purified commercial benzine, with an average boiling point of 140° F., containing small quantities of bodies boiling only at 392° F. and above it. Of these portions boiling at a high temperature, the oil tenaciously retains a small quantity, so that soap made from oil extracted with benzine has an odor of petroleum.

4. *Extraction with Ether.*

In most factories working on a large scale with carbon disulphide, experiments on as mall scale are generally made with ether.

It has been shown by numerous experiments that the seed is completely exhausted with ether, and the oil, after evaporation, is of an excellent quality. But, notwithstanding the fact that the advantages of ether over carbon disulphide, canadol and benzine were known, its use on a large scale never proved a success.

The loss by evaporation in an incompletely closed apparatus was feared, and the use of water, as with carbon disulphide, was not possible, the specific gravity of carbon disulphide being

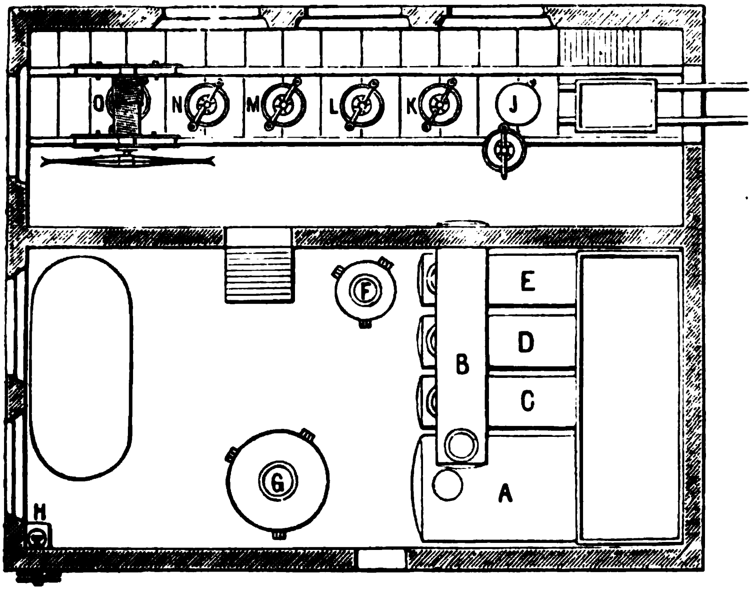
1.27, and that of ether only 0.72, and consequently the latter would not sink in water.

O. Braun has proposed the extraction of seed on a large scale by ether. It is claimed that the properties of ether as well as its low specific gravity and low boiling point are not hurtful, but rather beneficial, in an entirely closed apparatus.

On account of its low specific gravity, one pound of ether occupies nearly double the space of carbon disulphide, and as the solvents are used by measure and not by weight, the difference in price is almost annulled.

The low boiling point allows of a rapid and complete distillation of the ether from the oil and the residue.

FIG. 189.



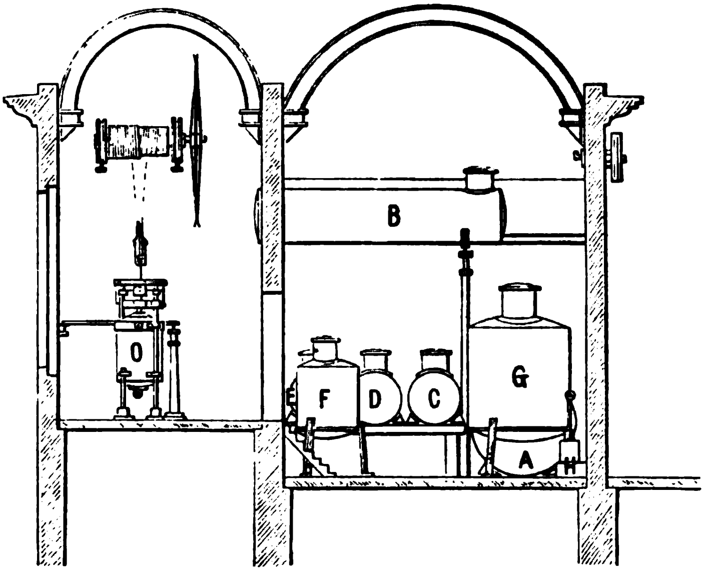
ETRACTING APPARATUS WITH ETHER. GROUND-PLAN.

Figs. 189, 190, 191 and 192 show the apparatuses for the extraction with ether; they can also be used with carbon disulphide.

The arrangement of the factory consists of a horizontal reservoir *A* capable of holding the entire quantity of ether (at the utmost 11,000 lbs.) used during the operation. *B*, *C*, *D*, and *E* are vessels of a similar form, their total capacity equaling that of *A*. *F*, *G* are two distilling vessels each provided with a cooling pipe. *H* is an air-pump, and *J*, *K*, *L*, *M*, *N*, *O*, six extracting vessels with vertical cylinders.

There is no gasometer.

FIG. 190.



EXTRACTING APPARATUS WITH ETHER. CROSS SECTION.

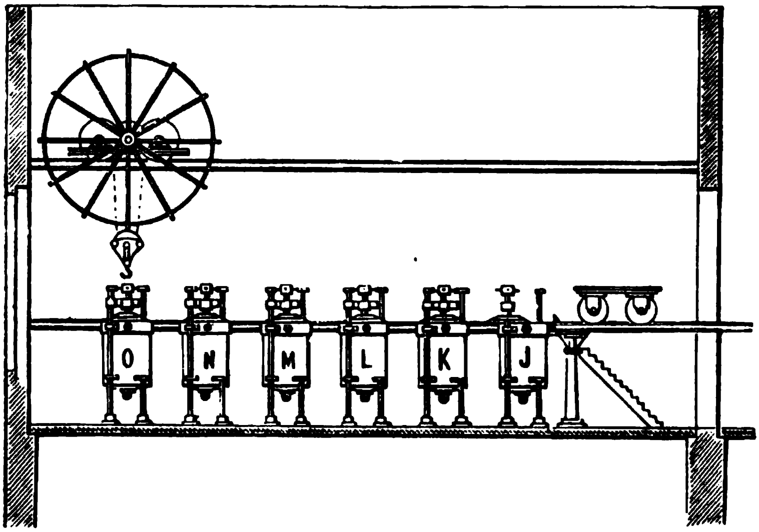
A, principal ether reservoir; *B*, *C*, *D*, *E*, reservoirs; *F*, *G*, distilling vessels; *H*, air-pump; *J*, *K*, *L*, *M*, *N*, *O*, extracting vessels.

All the vessels are of sheet-iron, closely riveted and hermetically closed, and connected with each other by cocks and pipes. The extractors, stills, and cooling pipes stand upon the floor, while three of the smaller reservoirs are placed about 3 feet lower, and the fourth reservoir, *B*, about 10 feet higher.

The extractors are 3½ feet high and 2½ feet wide, and have each a capacity of 550 pounds of crushed seed. They are emptied by lifting the lower perforated bottom with the entire contents by means of a traveling crane. This mode of emptying is very quick and convenient, the operation requiring only two minutes. The lid is simply pressed up and hermetically closed by a screw, so that it cannot be opened and closed in less than one minute.

The large reservoir *A* is placed lower than the three smaller ones; the motion of the fluid is effected by the air-pump *H*, each vessel being connected with the suction and delivery side.

FIG. 191.

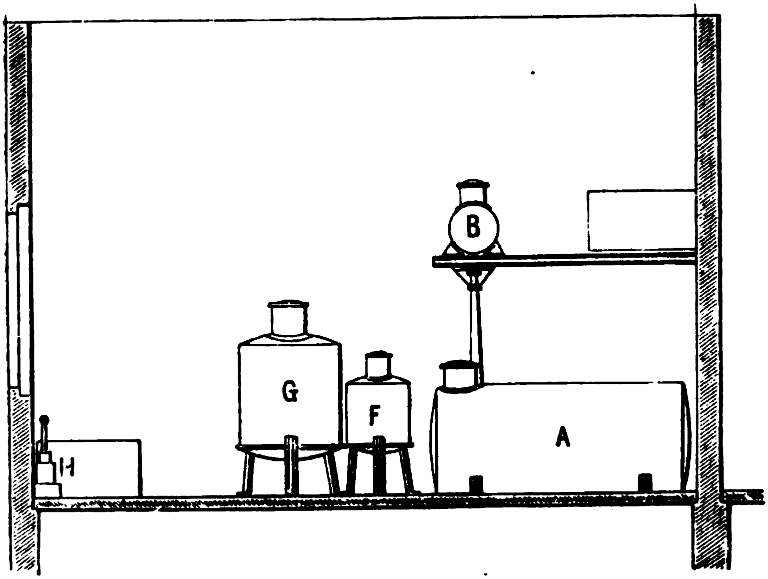


SECTION THROUGH THE EXTRACTING SPACE.

The progress of the operation is as follows: In the beginning all the ether is in the reservoir *A*. After charging the extractors *J*, *K*, *L*, *M*, *N*, *O* with crushed seed, the air from the upper reservoir *B* is pumped into the large reservoir *A*, so that the upper reservoir *B* is filled with ether. The air is then pumped from the first four extractors, *J*, *K*, *L*, *M*, and the first reservoir *C* of the three lower smaller reservoirs, into the large reservoir *A* and the upper reservoir *B*, and the ether admitted from below into the first extractor *J*. When *J* is full, the ether runs to the bottom of the second extractor *K*, which flows over into the third *L*, this to the bottom of the fourth *M*, and this finally to the first lower small reservoir *C*.

But before the overflow into *C* takes place the upper reservoir *B* is empty, and has to be refilled, as in the commencement of the operation, from the large resevoir *A*.

FIG. 192.



SECTION THROUGH THE DISTILLING SPACE.

When this is done, the ether is allowed to flow on in the manner described until a sample of it taken from above from the first extractor *J* evaporates without residue.

The flow of ether to the extractor *J* and the discharge from the extractor *M* into the reservoir *C* are then interrupted, and the cocks so placed that the ether flows from the reservoir *B* from below into the extractor *K*, from the top of *K* from below into the extractor *L*, from the top of *L* from below into *M*, from the top of *M* from below into *N*, and from the top of the extractor *N* into the reservoir *C*.

At the same time the air is removed from the second lower reservoir *D*, and also, by means of one of the serpentine pipes, from the second distilling vessel *G*. The latter is then connected with a cock on the bottom of the extractor *J* and the steam cock on the top of *J* slowly opened. The steam drives the ether into the distilling vessel *F*, where it first collects, and after being distilled by the hot steam following it, it is forced into the reservoir *D*.

In forty minutes every trace of ether is removed from the meal, so that on opening the extractor *J* only a pure seed odor is perceptible.

The concentrated oil solution which collects in the reservoir *C* is brought by suction and pressure into the distilling vessel *F*, and distilled.

The ether vapor is condensed by passing through the cooling pipe and flows into the reservoir *E*, from which it is returned to the principal reservoir *A*.

The consumption of ether, it is claimed, does not exceed one per cent. of the oil extracted.

The extraction of fat from bones, wool, etc., will be found in the chapter treating of " waste fats."

After the introduction of carbon disulphide for the extraction of oil there arose at once a dispute about the value and non-value of the method.

The farmer complained about the loss of the oil cake, as the residue left after extraction had a disagreeable sulphurous odor and was refused by the cattle. Oil dealers and soap manufactures objected to the disagreeable odor and taste of the oil, while the chemist claimed that the carbon disulphide would be partially decomposed, and besides would extract resinous and sticky substances which would promote the absorption of oxygen from the air, causing the oil to become rancid more quickly.

In consequence of all these objections, most of the factories in which the new system had been introduced did not prosper, and, with the exception of a few, stopped operations.

Another unfavorable circumstance was, that after the discovery of petroleum in America, large quantities of light volatile substances obtained in the distillation of petroleum were thrown on the market and were utilized as a substitute for carbon disulphide in the extraction of oil. The first patent for this method was granted in France to Richardson, Irvine, and Lundy.

Vohl's object was to obtain the oil as pure as possible, and for this reason he used a volatile petroleum ether boiling at 60° C. (140° F.), which does not dissolve resins, and applied the term canadol to it. Crude canadol contains, however, sulphur, and before use must be treated with potassium chromate and sulphuric acid, and several times rectified.

The opinions in regard to the advantages of canadol over carbon disulphide were formerly very much divided. Since the manufacture of carbon disulphide has, however, been perfected to such a degree that it is obtained absolutely pure and of a pleasant ethereal odor, and, moreover, can compete with canadol as regards price, the question whether its use be more suitable than that of canadol may be answered as follows: For the extraction of fine oils to be used for table and perfumery purposes, canadol is preferable; while for all other purposes, the market price of the two solvents must decide. One point in favor of carbon disulphide deserves mention. Extraction with it being carried on at an ordinary temperature, it is much simpler and is effected with less expensive apparatus than with canadol, and besides old seed is more completely exhausted.

The former complaints about the condition of the residue have long since ceased. The exhausted seed meal has not the slightest odor, and the demand for the oil cake became so great that the few factories in existence could not supply it. In consequence of this, and the extraction being much cheaper than in oil mills, which beside require a large capital, many new factories have sprung up during the last few years, and the trade is still growing.

Oil-extracting Plant.

From the previously given detailed descriptions of extracting seed-meal with carbon disulphide, canadol, benzine and ether, the accompanying illustrations, Figs. 193 and 194, of an oil-extracting plant according to Wegelin and Hübner's system, will be readily understood from the letters, and it remains only to mention the various apparatus required, viz.:

a. 8 extractors of cast iron, each about 4 feet in diameter and 3¼ feet high, provided with man-holes for charging and discharging the seed-meal, false bottoms, contrivances for the admission and discharge of benzine and steam, further with the necessary pipes for connecting the apparatus.

b. 1 cast-iron tank, 63 inches in diameter and 10 feet long, provided with man-hole and gauge, for the mixture of solvent and oil.

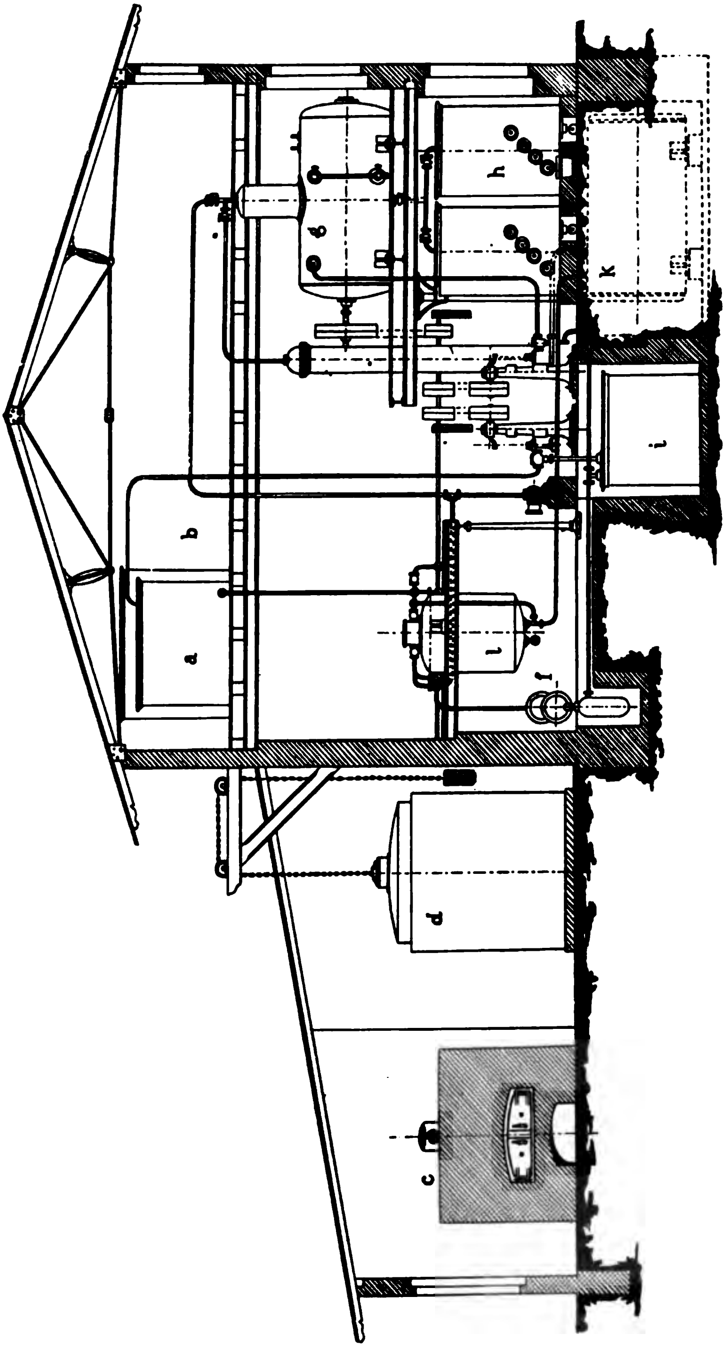
c. 1 still consisting of a horizontal wrought-iron cylinder, 5 feet in diameter and 10 feet long, provided with a stirring apparatus of broad flat wrought-iron paddles, further with a heating-coil on the bottom, valve for the admission of steam, discharge cock for condensed water, stirring apparatus with loose and fast pulley, gauge, stop-cock for interrupting the flow of mixture of oil and solvent, and discharge cock for the oil.

d. 1 vertical condenser for condensing the benzine, with about 215 square feet condensing surface, 55 cooling pipes, each about 1 inch diameter in the clear and 13 feet long, with inlet and outlet for water.

e. 1 tank for solvent, of about 175 cubic feet capacity, with man-hole and gauge, and inlets for the entrance of solvent from the condenser and other apparatuses.

f. 2 clarifying tanks, each of about 141 cubic feet capacity and 6½ feet high, provided with perforated steam-distributing pipe on the bottom, valve for cutting off steam, outlet for con-

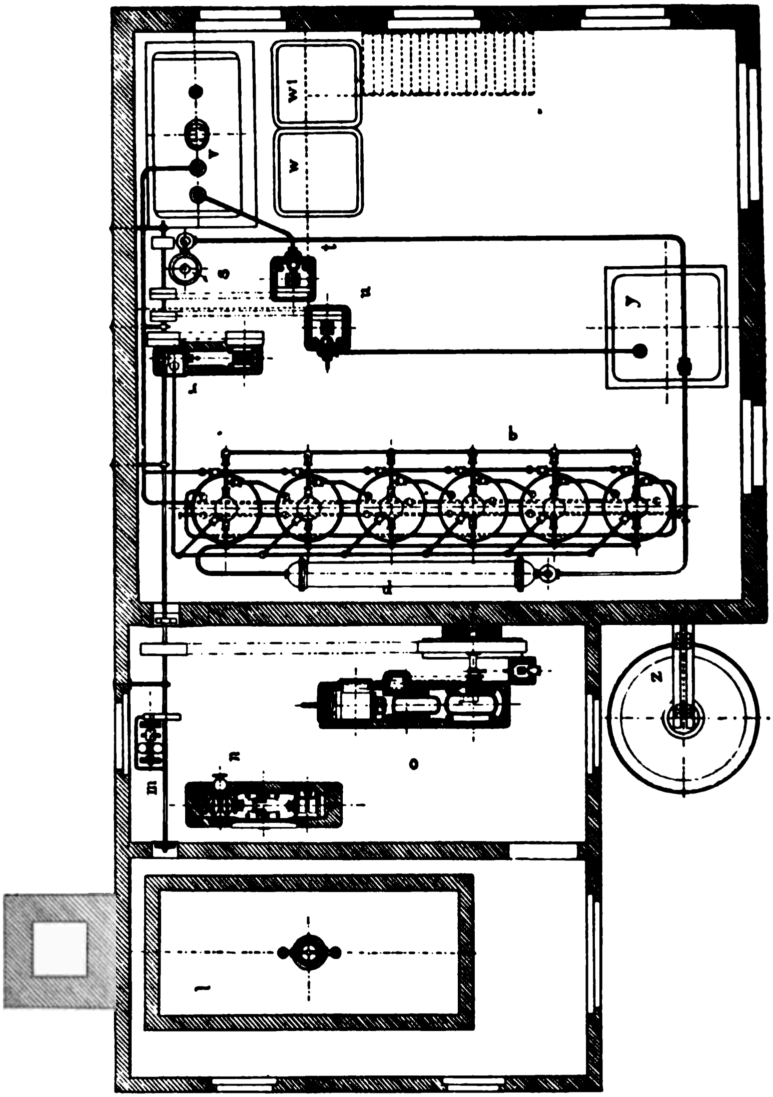
FIG. 193.



OIL-EXTRACTING PLANT ACCORDING TO WEGELIN AND HUBNER'S SYSTEM. LONGITUDINAL SECTION.

a, benzine tank; *b*, water tank; *c*, boiler; *d*, pressure-adjuster for benzine gas; *e*, extractor; *f*, condenser; *g*, still; *h*, clarifying tanks; *i*, benzine tank; *k*, tank for mixture of solvent and oil.

FIG. 194.



OIL-EXTRACTING PLANT ACCORDING TO WEGELIN AND HUBNER'S SYSTEM.
GROUND-PLAN.

l, boiler; *m*, electric-light plant; *n*, water-pump; *o*, steam-engine; *p*, condenser; *q*, extraction-battery; *r*, air-pump; *s*, condenser; *t*, pump for mixture of solvent and oil; *u*, benzine pump, *v*, tank for mixture of solvent and oil; *w*, *w'*, classifying tanks; *y*, benzine tank; *z*, pressure-adjuster for benzine gas.

densed water and heating coil on the bottom. Each tank is furnished at various levels with four cocks for the discharge of the finished oil, as well as with a cock and the bottom for the discharge of the residues.

g. 1 pump for pumping the solvent from the lower to the upper tank.

h. 1 horizontal condenser for condensing benzine or carbon disulphide and steaming the seed residues, with about 215 square feet condensing surface, 55 cooling pipes, each 1 inch diameter in the clear and 13 feet long, with inlet and outlet for water.

i. 1 solvent-separator, which separates the water from benzine and carbon disulphide, so that only pure solvent flows back to the tank.

k. 1 vacuum pump of 7¾ inch cylinder diameter and 10¼ inches stroke, with loose and fast pulley.

l. 1 crushing-roll with 2 rolls, each 15¾ inches in diameter and 19¾ inches long.

m. 1 gasometer, 7¼ feet in diameter and 6½ feet high, for absorbing air containing solvent.

CHAPTER XII.

PURIFICATION OF OIL.

THE object of purification or refining is to remove the coloring, mucous, and albuminous substances which give to the oil a milky turbidity and a great tendency towards rancidity. A great part of these matters, and all bodies merely in a state of suspension, are, of course, deposited by repose for a sufficient length of time; but as this process is slow, it is necessary, in order to clarify the oil completely, to employ other means. The method generally adopted is treatment with sulphuric acid, which was first made use of by Gowen, and improved by Thenard.

Oils cannot resist the energetic action of concentrated acids. If the power of these acids, however, is weakened by lessening the quantity used, their effect is especially directed towards the withdrawal of water and the destruction of the foreign matters in admixture, which are separated in a flocculent, partially carbonized condition.

Sulphuric acid, for example, in the proportion of three-quarters to one and a half per cent. of the oil, acts as depurating agent, precipitating the mucilage and parenchymatous matters: first by its powerful dehydrating action it removes the water by which these substances were held in solution by the oil, and afterwards chars the mucous matters themselves, thus rendering them insoluble or otherwise effecting their destruction. The oil itself would be next acted upon to a certain extent by the decomposition of a part of the fat into glycerin and fatty acids, the latter remaining dissolved in the oil. This decomposition would extend still further if two or more per cent. of sulphuric acid were used, whereby the oil would lose in quality and become limpid and of no value.

The process of refining is divided as follows:—

1. Addition of the sulphuric acid, and intimate mixing with the oil.

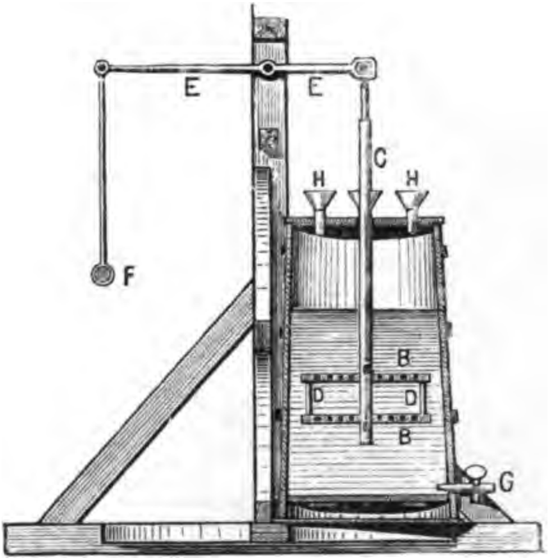
2. Allowing the carbonized mass to settle as a flocculent deposit upon the bottom.

3. Removing adhering sulphuric acid by washing.

4. Filtration.

For the first operation the oil, heated to 86° F., is brought into vats open on top, and three-quarters to one per cent. of sulphuric acid added in a thin stream, with constant stirring.

FIG. 195.



STIRRING APPARATUS WORKED BY HAND.

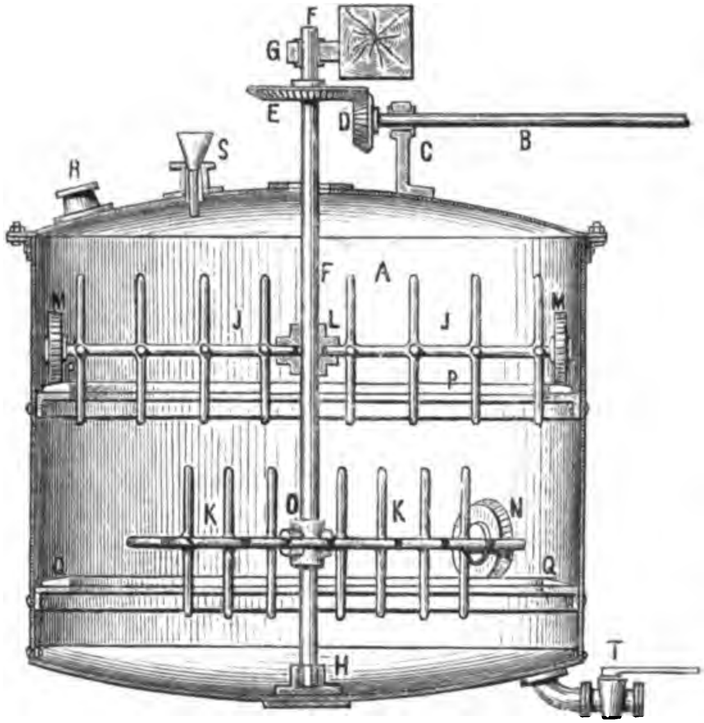
A, vat; *B*, wooden rings; *C*, wooden rod; *D*, connecting rods; *E*, lever; *F*, handle; *G*, cock; *H*, glass funnels.

For mixing the acid with the oil an up-and-down motion is preferable to a circular one. An apparatus worked by hand effecting this is shown in Fig. 195.

The oak vat *A* serves for mixing the oil with the acid. The actual stirrer consists of two wooden rings *B* placed six to eight inches apart on the wooden rod *C* and connected by the rods *D*. An up-and-down motion is imparted to the stirrer, which is connected with the lever *E*, by working the handle *F*.

To protect the vat from impurities, it is provided with a lid through which pass the rod *C* and the glass-funnels *H*. The oil mixture is discharged through the cock *G*, placed immediately above the bottom of the vat.

FIG. 196.

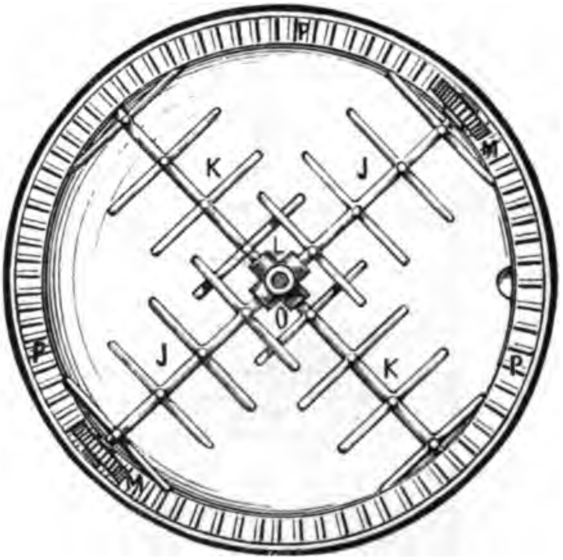


STIRRING APPARATUS. VERTICAL SECTION.

A, vat; *B*, transmission shaft; *C*, brasses: *D E*, bevel gear; *F*, vertical shaft; *G*, brasses; *H*, step; *J*, upper system of arms; *K*, lower system of arms; *L*, hub of upper arms; *M N*, bevel-wheels; *O*, hub of the lower arms; *R*, inlet for oil; *S*, funnel; *T*, discharge-cock.

Figs. 196 and 197 show a stirring apparatus driven by machinery. It consists of the sheet-iron mixing vat *A*, lined with lead; motion is transmitted from the shaft *B*, which lies in the brasses *C*, to the vertical shaft *F*, by the two bevel-wheels *D* and *E*. The shaft *F* has its bearing in the brasses G and the step *H*. Two systems of arms, connected with the shaft by the hubs *L* and *O*, revolve around their vertical axis. This would, however, give to the oil mixture only a circular motion, without stirring it together. To effect the latter a horizontal motion is also required, which is obtained by the horizontal shaft of the arms revolving in the hubs *L* and *O* by means of the bevel-wheels *M* and *N*.

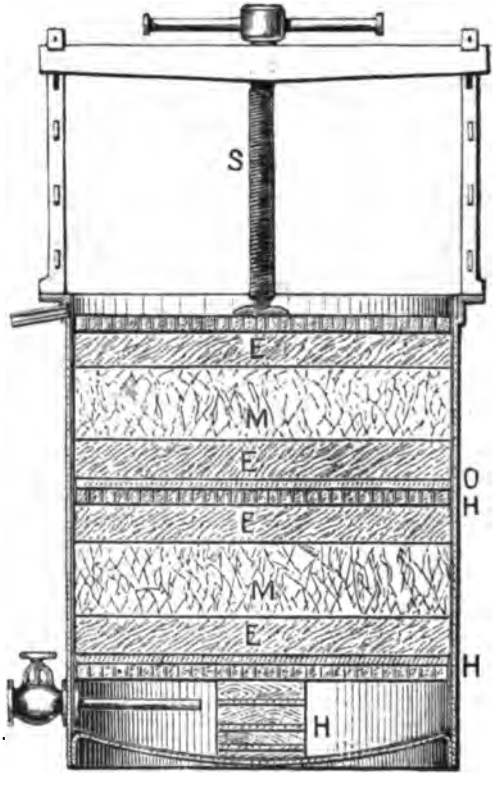
FIG. 197.



STIRRING APPARATUS: GROUND-PLAN.

The oil is introduced into the mixer through *R*, and the sulphuric acid added in drops through one or more glass or lead funnels *S*. Stirring is continued three-quarters to one hour, according to the condition of the oil. The oil itself becomes dark by the operation, and after six to twelve hours yields a flocculent deposit of the same color, becoming itself perfectly bright and clear. It is then discharged through the cock *T* into a vat placed at a lower level than *A*, and several times washed with hot water, with vigorous stirring. It is then brought into the clarifying vats, where it remains until completely separated from the water. Separation is facilitated by an addition of about five per cent. of common salt.

FIG. 198.



OIL FILTER.

E, tow; *H*, cross-beam; *S*, screw; *M*, layer of moss; *O*, linen.

Filtration.—Felt bags were formerly in general use for this purpose, but they had the disadvantage of becoming quickly and repeatedly clogged with solid matter, and cleansing the bags was very tedious. Later on vats with conical openings in the bottom stopped with cotton plugs were used, but they also would choke up and become impermeable to the oil. Though this process is still used in some refineries, a much better method is to pass the oil through a filter shown in Fig. 198, working only with linen, tow and moss.

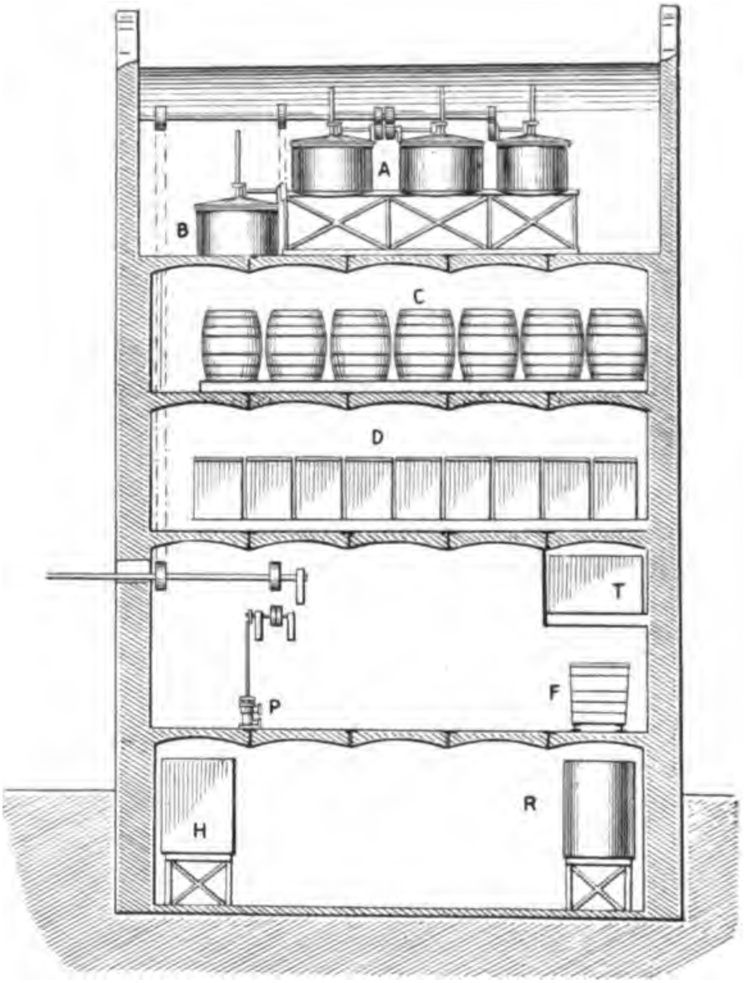
The iron filter-box, lined with lead, is fed from a basin placed at a higher level. On the bottom of the filter is the cross-beam *H*, carrying a perforated wooden plate covered with a layer of coarse and one of somewhat finer linen, *O;* then follows a thin layer of tow, *E*, and upon this a layer of moss, *M*, and linen; then again a wooden plate, and so on in the order mentioned. The screw *S* does not only assist in packing the filter, but the filtering operation itself can be regulated by tightening or loosening it.

Moss (*Hylocomium triquetrum*, Schimp; *Hypnum splendens*, Hedw.; *Polytrichum commune*, L.) is especially adapted for the purification of oil, and can also be used for filtering oils not previously treated with sulphuric acid. In using it by itself for packing the filter, an arrangement for convenient compression must be provided.

The packing must be renewed about every three weeks. The material no longer fit for use is subjected to strong pressure to obtain the oil, and then treated with hot water.

Refining plant.—Figs. 199 and 200 exhibit the arrangement of an oil-refinery. It is located in a separate building from the oil-mill. The crude oil is directly pumped by the pump *P* into the stirring or mixing tanks *A* located on the top floor. According to its quality the oil is mixed with ½ to 1½ per cent. of sulphuric acid and thoroughly worked with a mechanical stirrer —*p*—for about 1 hour, though sometimes it is of advantage to continue stirring for a longer time. Stirring being finished, the oil is allowed to repose for about 5 hours or longer, to give the acid and separated flakes time to settle. Each stirring-tank is provided with a cock for discharging the oil into the wash-tank *B*, and another cock in the lowest part of the bottom for removing the acid and the precipitated flakes.

FIG. 199.

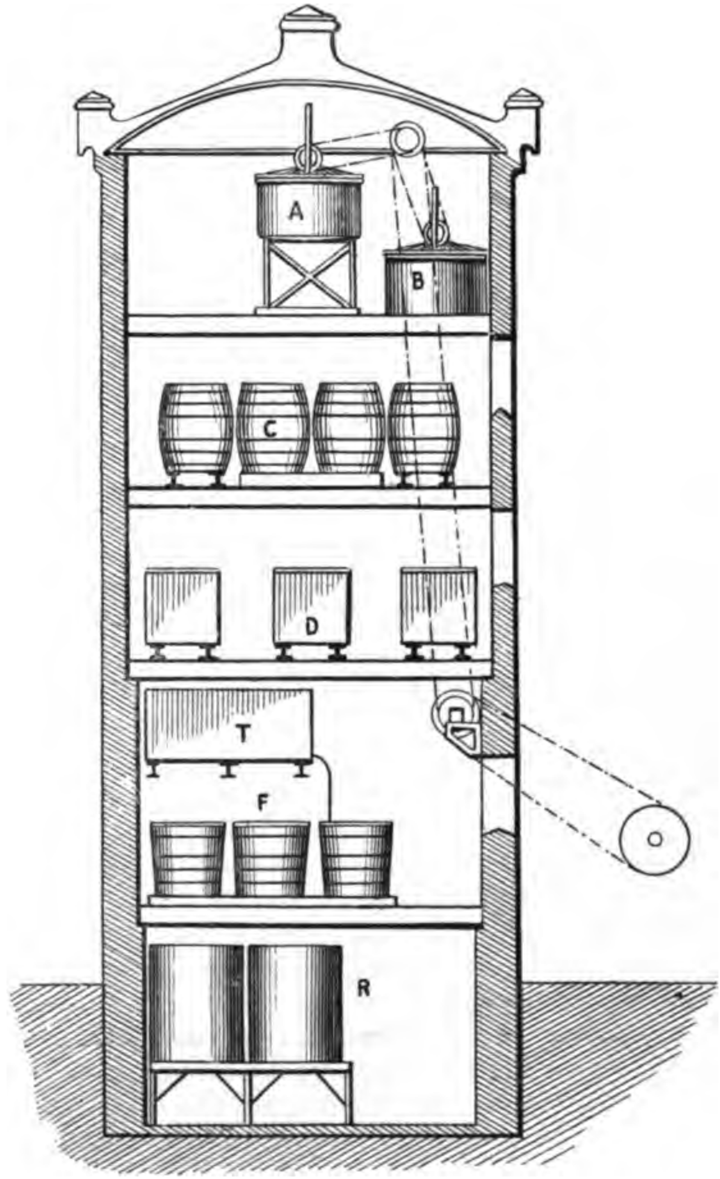


OIL REFINERY.

Vertical section.

There should be at least three or four stirring tanks, while for the subsequent washing one tank also provided with a stirring apparatus suffices.

FIG. 200.



OIL REFINERY.

Cross section.

A, stirring-tank : *B*, wash tank ; *C*, wooden settling vats ; *D*, iron settling tanks ; *F*, filter ; *H*, reservoir for crude oil ; *P*, pump ; *R*, reservoir for refined oil ; *T*, tank for oil to be filtered.

The oil discharged from the stirring-tanks is mixed with about 20 per cent. boiling hot water and stirred at least one hour. The water required for washing is heated in a small reservoir by means of steam from the boilers.

From the wash-tanks the oil is discharged into the settling-tanks *C* and *D*, where it is allowed to settle from four to six days. Of these settling tanks there should be as large a number as possible, the quality of the oil later on depending very much on its being free from water.

The stirring and mixing vats are of iron lined with lead; the settling tanks *D* may also be of iron, though wooden vats *C* suffice for the purpose.

The various stories of the building are connected by pipe-lines, so that one workman can conveniently attend to all the various operations. On the side near the bottom of the settling tanks are two cocks one above the other, the deposited water being drawn off through the lower cock and the oil through the upper. This work being finished the principal operation—filtering—commences, the previously-described filter (Fig. 198), which is fed from the tank *T*, beimg used for the purpose. The number of filters depends on the magnitude of the refinery.

The waste in refining oil amounts to 1½ or 2 per cent.

The residues from refining, the waste from the settling tanks, vats and the oil from the worn-out filters, hold oil which should be utilized, and it is therefore recommended to place in the basement of the refinery a tank which can be fed by steam. The residues collected in this tank are boiled by direct steam, and after an addition of common salt, good serviceable oil separates in two or three hours.

The deposits from the stirring-vats may also be otherwise utilized. They contain not only the carbonaceous products of decomposition due to the action of sulphuric acid upon the mucilaginous and albuminous portions, but also combinations of sulphuric acid with fatty acids—the so-called Fremy's acids—oleo-sulphuric, stearo-sulphuric, palmito-sulphuric and glycero-sulphuric acids. These acids have the appearance of oil, and by boiling with oil are again resolved into sulphuric acid and fatty acids. Upon this decomposition is based the use of sulphuric acid residue from oil refineries in beet-sugar factories, in tawing and for pickling sheet-iron intended to be tinned.

In refining with sulphuric acid, Michaud assists the mixing process by injecting a strong current of air, whereby the decomposed substances are forced to the surface in the form of a dark-colored scum, which is removed. As soon as the scum appears colorless, the introduction of air is interrupted and the oil heated by the direct introduction of steam. The condensed water absorbs the acid and is discharged from time to time.

The oil-refining boiler, Fig. 201, is a more recent apparatus, and turbid oils treated in it, in a short time become bright.

The boiler *A* is provided with the coil *D*, which proceeding from the lid returns to it after many turnings. Upon the lid sits a pipe carrying a vessel *R* with the air ejector *E*. This ejector produces in the beginning of the operation a *vacuum* in the upper part of the boiler, which is filled about two-thirds with oil.

When the *vacuum* becomes larger, fresh atmospheric air enters through the pipe *L* and produces a lively motion in the oil heated by the coil *D*.

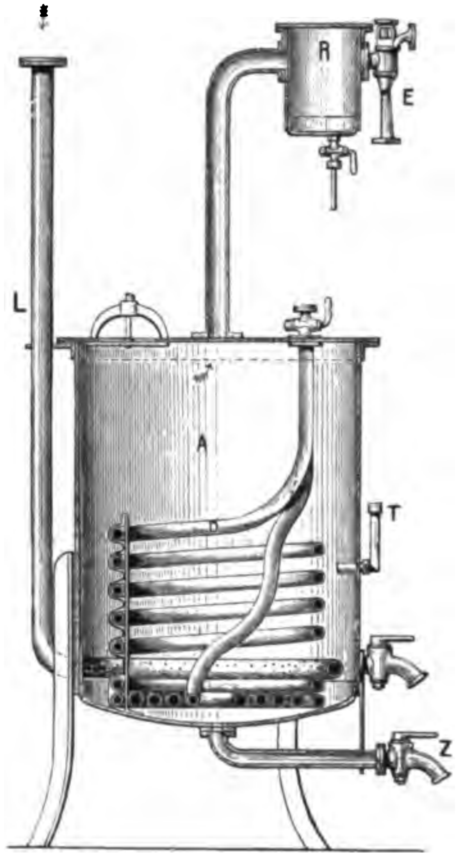
By the motion of the oil and the high temperature, the water mechanically fixed is removed and a chemical effect exerted upon the oil by the oxygen of the air.

Oil treated with this apparatus is as bright and clear as if it had passed through all the refining processes.

Steam may also be introduced into the apparatus. The precipitates formed deposit rapidly on the bottom, and can be removed through the cock *Z*. The water present is readily evaporated by adjusting the ejector.

The action of the ejector is so powerful that the temperature is increased as much as 50° F. This may be ascertained by the

FIG. 201.



OIL-REFINING BOILER.

A, boiler; *D*, coil: *E*, air-ejector; *L*, air-pipe; *R*, vessel; *T*, thermometer; *Z*, cock.

the thermometer *T*, which passes into the boiler and is required for various purposes.

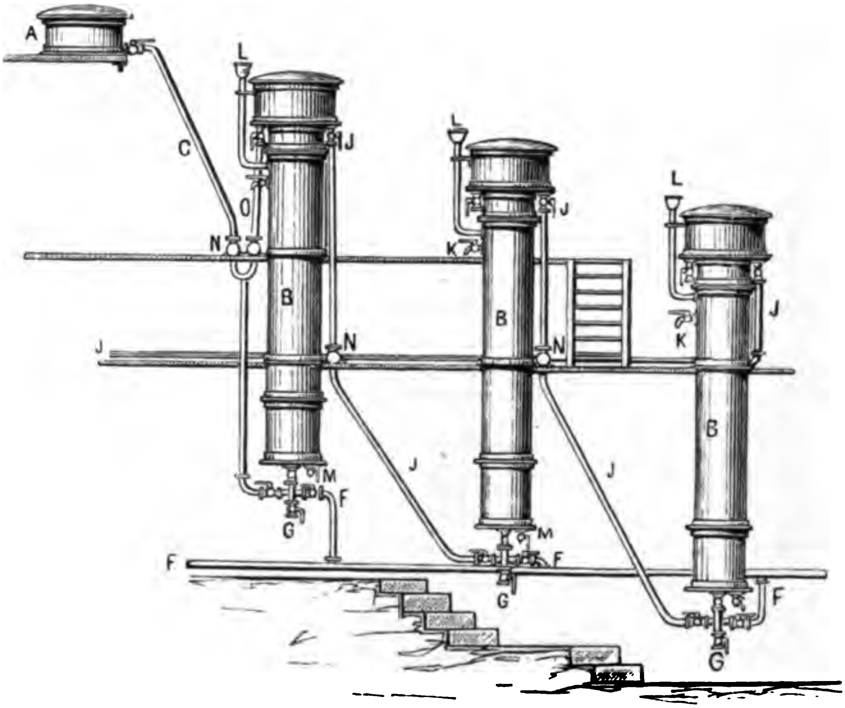
This apparatus is of special importance for machine and table oils. The waste and loss amount to scarcely one per cent.

Raymond-Combret apparatus.—With this apparatus the oil is purified by passing it in fine jets through different acids or salt solutions.

The purification is effected in the cylinder *B*, Figs. 202 and

203, of which there are several to make the operation a continuous one. The oil is in the reservoir *A*, and passes through the pipe *C* and the rose *D* to the iron cylinder *B*, tinned inside. The latter, which has a somewhat larger diameter near the top, and is closed with a lid, is filled with water. The pipe *C* conducts the oil to the pipe *E*, which is connected with the steam-pipe *F*, by means of which the purifying liquids can be heated. The pipe leading downwards, and provided with the cock *G*, serves for cleaning *E*.

FIG. 202.

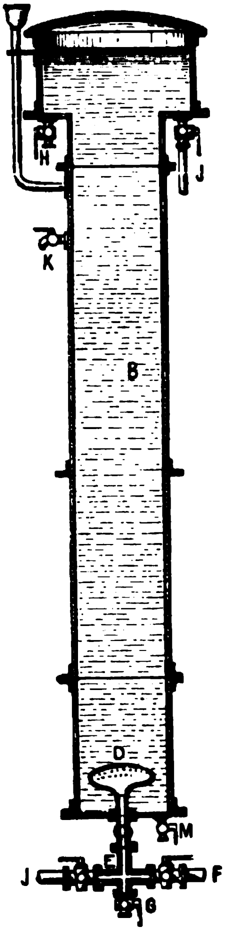


OIL-PURIFYING APPARATUS. GENERAL ARRANGEMENT.

A, oil reservoir; *B*, three purifying cylinders; *C*, conduit from oil reservoir; *D*, rose; *E*, pipe; *F*, steam-pipe; *G*. cock for cleaning *E*; *H*, discharge cock; *J*, cock and conduit; *K*, discharge-cock for water; *L*, water conduit; *M*, cock for emptying *B*; *N*, rotary pump; *O*, oil conduit.

Through the rose *D* the oil enters the cylinder in a uniform manner, passes through the water column, or a column of liquid containing various acids or salts, and collects in the top.

FIG. 203.



OIL PURIFYING APPARATUS. PURIFYING CYCLINDER.

The cock *H* serves for the direct discharge of the oil, while the cock *T* conducts it into the next cylinder or the filtering apparatus.

The level of the water in the cylinder can be exactly brought to the height of the cocks *H* and *J* by discharging water through the cock *K*, or admitting it through the pipe *L*.

The cylinder *B* is emptied through the cock *M*. In arranging several cylinders, they must be so placed that the bottom of the upper wider portion stands somewhat higher than the top of the next one, so that the oil can flow by gravity from one vessel into the other, thus passing through all the cylinders and reaching the filtering apparatus from the last one through the pipe *J*.

It is of great advantage to place small rotary pumps *N* in the pipes *J* and *C* to increase the velocity of the flow of the oil to the cylinder, and, if necessary, to reconduct the oil through the pipe *O* to the bottom of the same cylinder.

By this method it is possible to use various chemical substances employed in the purification of oil, such as sulphuric acid, solutions of chromates, manganates, etc., according to the effect to be produced.

Besides purification with sulphuric acid, a number of other methods have been proposed, the best being Bareswil's, which is based upon an incomplete saponification.

The oil is compounded with two to three per cent. of quicklime or caustic soda lye and the mixture gradually heated. The soap separated forms a stiff lather enveloping the foreign substances, which become insoluble and are deposited, together with the soap, on the bottom. The supernatant clear oil is separated by pouring off and filtering through linen. The residue is used in the manufacture of soft soaps.

Liquid caustic ammonia, used by R. de Kayser for the same purpose, has the disadvantage of forming an emulsion difficult to separate from the fat.

According to Dubrunfaut, oil-cake meal stirred together with the oil and allowed to stand a week gives clear oil without filtration. The ability of the meal to absorb impurities is claimed to be so great that the same quantity can be used 20 to 30 times in succession. The exhausted oil cake is finally subjected to pressure, which is troublesome, and then yields oil cake scarcely fit for feed.

Instead of sulphuric acid R. von Wagner used a concentrated solution of chloride of zinc, which does not act upon the oil but destroys the impurities. For 100 parts by weight of oil 1½ parts by weight of chloride of zinc solution of 1.85 specific gravity are used.

In many refineries infusion of nut-galls or solution of tannin is used for the separation of the albuminous substances. This method gives, however, not very favorable results, as the separation of the mucilaginous substances still present is only partly effected, which renders clarification very difficult.

As is well known, the oil, after coming from the press, has to repose eight days or longer for clarification. On account of a sudden rise in the market, or for some other reason, this loss of time may occasionally be of great disadvantage to the manufacturer.

Experiments in clarifying the oil with a centrifrugal machine were made some time ago by Mr. Mayer, superintendents of the Hernals oil refinery, but have been abandoned, the results not being as favorable as expected.

CHAPTER XIII.

RENDERING TALLOW AND LARD.

Rendering tallow. This operation is generally conducted according to one of the following three methods:—

1. Over an open fire.
2. Over an open fire with sulphuric acid.
3. By steam.

Rendering over an open fire is the oldest method. The fat, chopped fine, is brought into a copper boiler bricked in so that only the bottom comes in contact with the fire. A small percentage of water is added, this being especially necessary in summer, when the tallow has lost much moisture by evaporation. The tallow, which is enclosed in cellular membranes, soon begins to melt after the fire is started, and, as the temperature in the boiler increases, runs from the membranes, which are burst by the heat. The mixture of fat bubbles and water gives to the liquid a milky appearance, but after the evaporation of the greater portion of water, the cell membranes become more contracted and the fat appears clear.

During the entire period of heating, which lasts one to one and a half hours, the mass must be constantly stirred with a wooden paddle to prevent the membranous substances from settling on the bottom and scorching.

When the fat ceases to throw up bubbles and appears clear on the surface, the fire is slackened and preparation made for the separation of the fat from the greaves or cracklings, as the membranous residue is called.

For this purpose the greaves are pressed down by a strong sieve or copper sheet, and the tallow penetrating through the meshes is ladled upon a linen cloth into a filtering basket resting upon another boiler, to remove the impurities as much as possible. When all the tallow is ladled out and the greaves freed as much as possible from fat by compression, the latter are placed in a woolen or hair-cloth press-bag and the fat retained by them regained by pressure with an ordinary screw-press.

Generally speaking, 80 to 82 per cent. of rendered tallow and 10 to 15 per cent. of greaves are obtained, though very pure, dry tallow may yield as much as 90 per cent. and more.

The greaves were formerly burnt under the boiler or fed to dogs, chickens, and hogs. But in many places they form at present an article of commerce, as they contain about ten per cent. of fat, which can be extracted by a suitable solvent, such as benzine or carbon disulphide, and used in the manufacture of lubricants. The exhausted residue, if not burnt, is used in the manufacture of glue, potassium ferrocyanide, or manure.

On account of the noisome odors developed, rendering tallow over an open fire is not allowed in most cities or in the neighborhood of habitations, without suitable arrangements for the removal of the noxious gases.

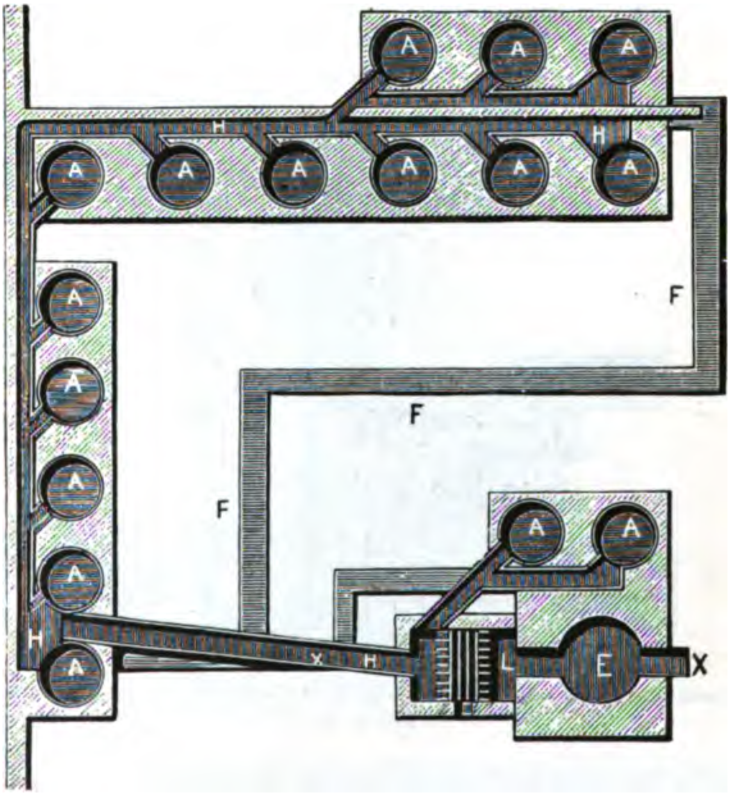
The simplest method is to provide the boiler with a well-fitting lid with a pipe through which the gases escape into the chimney, and hence into the higher strata of the air. There must be, further, a stirring apparatus, consisting of a shaft standing in the centre of the boiler and provided below with arms and on top with a crank. Through the opening in the lid through which the stirring apparatus passes, air is sucked in by means of the chimney, and the gases are carried off.

This can, however, only be effected with a very strong draught, as otherwise the gases would escape through the opening before reaching the chimney.

This arrangement is rather incomplete, but good results are obtained by burning the gases in the manner shown by Figs. 204, 205, and 206.

There are 16 boilers A, each provided with a helmet B, with a pipe-like shoulder, and the man-hole *C* for charging and emptying A. The helmet B is connected with the suction flue *H*, about 2½ feet high and 1¾ feet in diameter, which carries the gases under a small furnace *G*, placed directly on the foot of the chimney *E* and heated to a white heat, where they are completely burned.

FIG. 204.



RENDERING TALLOW OVER AN OPEN FIRE WITH DISINFECTING FURNACE.
GROUND-PLAN.

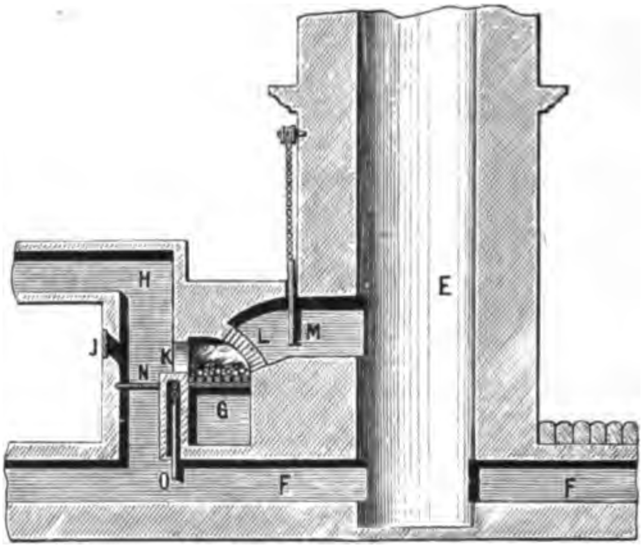
_A_, boiler; _B_, helmet; _C_, man-hole; _D_, fire-place for each boiler; _E_, chimney; _F_, smoke-flue for all the fire places; _G_, auxiliary furnace; _H_, suction-flue toward _G_; _J_, opening for the admittance of air; _K_, perforated plate; _L_, fire-proof vault; _M_, vertical slide; _N_, horizontal slide; _O_, vertical slide.

The flue *F* connects all the fire-places with the chimney *E*.

For very large establishments an opening *J* is provided for the admittance of air, in case the gases, on arriving under *G*, should not contain sufficient oxygen for their complete combustion.

Between the suction-flue *F* and the furnace *G* is a perforated plate *K*. The gases passing through these perforations arrive under *G* in a divided state. The products of combustion of *G* and of the gases and vapors entering through *K*, pass through openings into the fire-proof vault *L*, and thence into the chimney *E*. Coke is burned in the furnace *G*, so that the products of combustion contain as little aqueous vapor as possible.

FIG. 205.



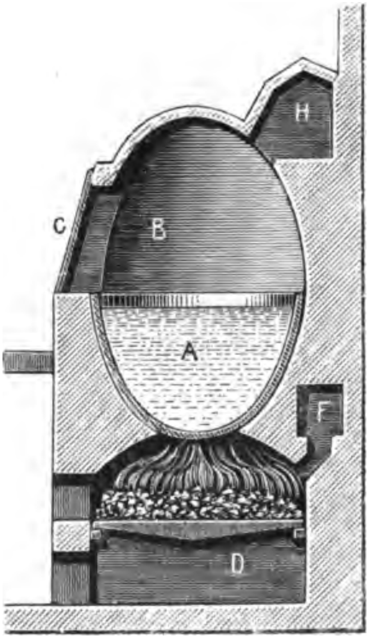
RENDERING TALLOW OVER AN OPEN FIRE WITH DISINFECTING FURNACE. SECTION FROM X TO X.

M is a vertical slide to interrupt the connection between *G* and *E*, while the horizontal slide *N* serves for establishing connection between the flue *H* and the flue *F*, to carry off the vapors through one of these flues while the fire is kindled in *G*.

By another vertical slide *O*, the smoke from the fire-places can also be conducted through the fire place of *G*, provided the horizontal slide *N* be open.

Rendering with acid.—The method most in use in recent times is to render the tallow with an addition of dilute sulphuric acid over an open fire.

FIG. 206.



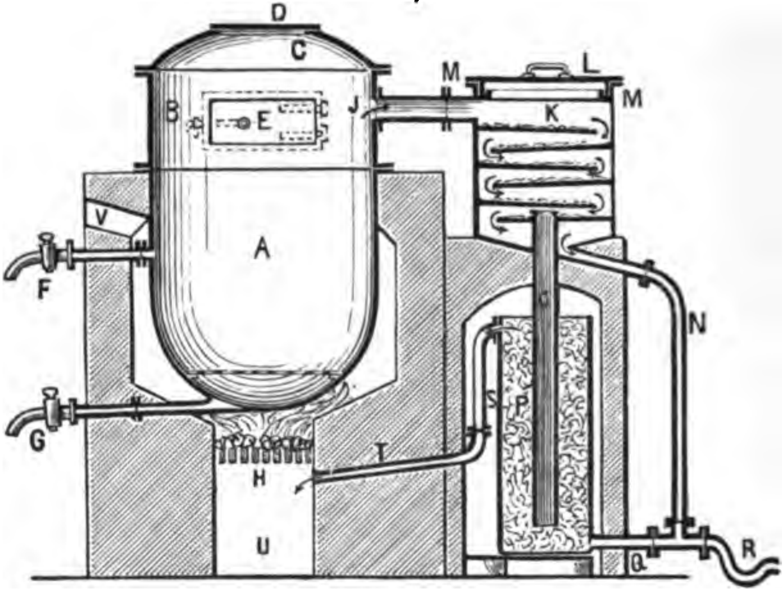
SECTION THROUGH A RENDERING BOILER.

The sulphuric acid effects the chemical destruction and opening of the cells. For 100 parts by weight, 20 parts by weight of water compounded with ½ to 1½ parts by weight of sulphuric acid are used.

Though this method has not so many disadvantages as the preceding one, great care must nevertheless be exercised to remove the noisome exhalations developed, which, however, cannot be effected by combustion.

Vohl's apparatus (Fig. 207) is well adapted for the purpose. It consists of the cast-iron boiler *A*, lined with lead, the cylindrical head-piece *B*, and the lid *C*, which is provided with a mica plate *D*; another mica plate is in the door *E*, both serving for observing the processes in the interior of *A*. At night a light is placed over the mica plate in the lid.

FIG. 207.



RENDERING BOILER WITH ACID OVER AN OPEN FIRE.

A, boiler; *B*, cylindrical head-piece; *C*, lid; *D*, mica plate; *E*, door; *F*, cock for the discharge of the tallow; *G*, cock for the discharge of the acid liquid; *H*, grate; *J*, connecting pipe between the boiler and condensing box *K*; *L*, lid of condensing box; *M*, sand packing; *N*, discharge-pipe; *O*, pipe for non-condensed gases; *P*, condenser: *Q*, discharge-pipe; *R*, outlet; *S*, pipe for non-condensed gases; *T*, flue for non-condensed gases; *U*, ash-pit; *V*, flue.

The tallow is introduced through the door *E*, which also serves to close hermetically the cast-iron head-piece *B*. After the operation of rendering is finished the tallow is discharged through the cock *F* and the acid liquid through the cock *G*, while the cracklings or greaves remaining upon a perforated plate in the boiler are removed through the door *E*.

The gases and vapors developed during rendering in the boiler *A* pass through the pipe *J* into the condensing box *K*. The latter is closed with the lid *L*, provided with sand packing at *M*.

In the interior of *K* are oblique scaffolds covered with decomposed lime. The box itself consists of wood saturated with asphaltum or tar. The water condensed in it runs off through the pipe *N*, the escape of gases being prevented by the curvature of *R* forming a trap.

The gases and vapors not condensed in *K* pass through the pipe *Q* into the condenser *P*, which is lined with lead and filled with coke or pumice-stone saturated with sulphuric acid. The liquid collected here passes through the pipe *Q* to the discharge-pipe *R*.

The non-condensed gases, etc., are finally conducted through the pipe *S* into the channel *T*, which leads into the ash-pit *U* under the grate of the fire-place *H*.

The non-condensed gases, etc., being almost completely freed from aqueous vapors by passing through the condensers, can be unhesitatingly admitted under the grate without fear of disturbing the draught.

The ash-pit *U* is closed with an iron door, whereby a strong draught is produced which sucks all the gases from the apparatus into the grate. The gases of combustion escape to the flue *V*, which leads to the chimney.

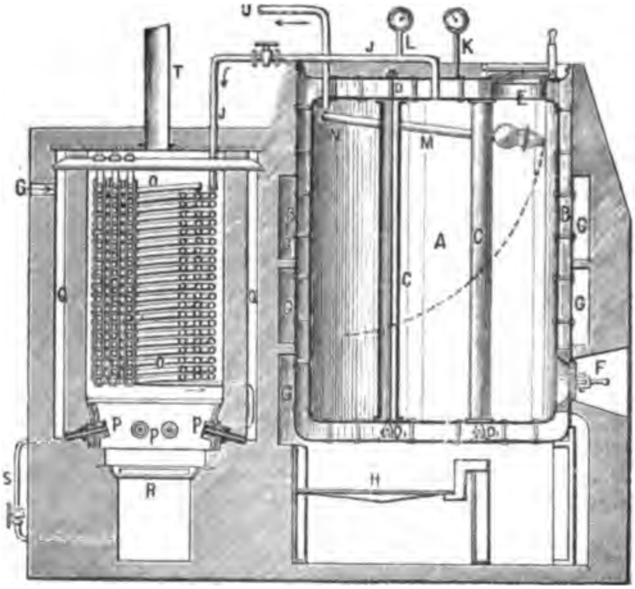
Rendering by steam.—An apparatus for rendering tallow by steam is shown in Fig. 208. Its principal advantage consists in the complete destruction of the noxious vapors and the safety from explosions, as the fat in the digester is melted very gradually.

The apparatus consists of two parts, a boiler or digester and a furnace for burning the developed gases and vapors, both being connected by the pipe *J*. The digester, which receives the fat to be rendered, consists of the steam-tight cylindrical boiler *A*, surrounded by the jacket *B*.

To secure greater solidity, as the digester must stand a hydraulic pressure of seven atmospheres, the bottoms are connected with the inner walls by the rods *D*, and the jacket by stays. The steam-pipes *C*, which serve for uniformly heating the fat, contribute also to the strengthening of the digester.

Underneath the digester, which rests upon supports, is a fire-place, from which the gases of combustion, after passing through the flues *G* in the brickwork over as large a surface of the digester as possible, escape into the chimney.

FIG. 208.



STEAM-RENDERING APPARATUS.

A, digester; *B*, jacket, *C*, steam-pipes; *D*, strengthening rods; *E*, man-hole; *F*, opening for removal of residue; *G*, flues; *H*, grate; *J*, connecting pipes; *K*, manometer of jacket; *L*, manometer of digester; *M*, pipe with strainer; *N*, swivel joint; *O*, pipe system; *P*, burners; *Q*, opening and air-chamber; *R*, grate; *S*, small pipe; *T*, chimney; *U*, discharge-pipe.

The digester is filled through the man-hole *E*, and the membranous residue removed through the opening *F*.

The pipe *M*, turning in the swivel joint *N*, and provided on the end with a strainer to prevent the escape of foreign substances, serves for the removal of the liquid fat. With the pipe *M* communicates the discharge-pipe *U*, by which the liquid fat can be conveyed to any desired place by the pressure prevailing in the digester *A*.

The gases and vapors developed in rendering escape through the connecting pipe *J* into an Argand furnace, so called by the inventor.

The gases pass here first through the heated pipe system *O*, and enter from below four burners, *P*, symmetrically arranged in a circle, where they are mixed with atmospheric air, ignited, and burned.

The gases of combustion, in ascending, pass around the spirals *O* and escape through the chimney *T*.

The air required for combustion enters at *Q*, in the upper part of the furnace, an air-chamber in the brickwork, where it is heated and passes from below into the burners.

To promote the draught in the digester, the small pipe *S* conducts heated gas into the space below the grate *R*.

The operation of rendering the tallow is conducted as follows:

After filling the jacket *B* with water to the highest point of the flues, and heating the boiler, the digester *A* is charged with the fat to be rendered, care being had to place the strainer *M* at its highest point. The Argand furnace is heated at the same time by kindling a fire upon the grate *R*.

As soon as the manometer *K* indicates a moderate pressure the cock on the discharge-pipe *J* is opened and the gases escape to the combustion furnace, where, in the meantime, sufficient heat must be developod to assure complete combustion of the noisome vapors.

The heating of the digester is so regulated that the tension of the steam in the jacket is not over 4 atmospheres, and the pressure in the digester not over 2.5.

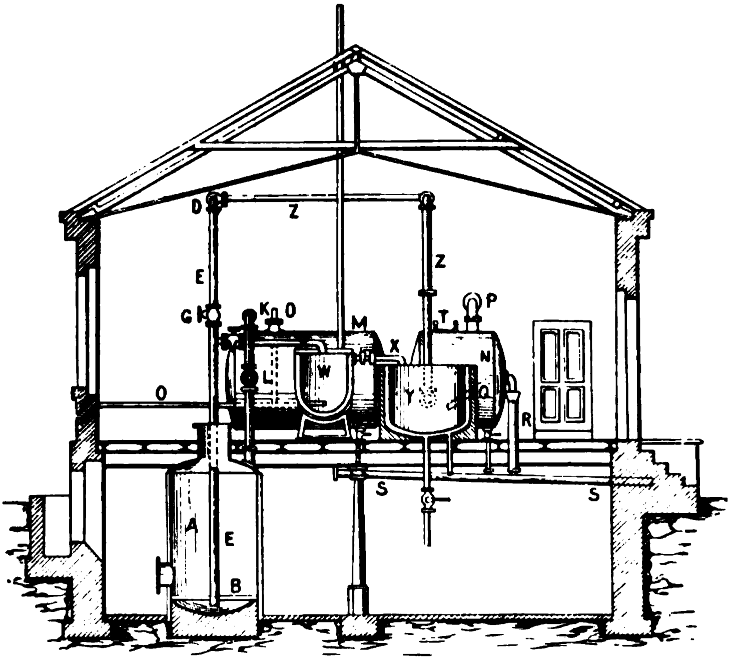
To recognize the moment of complete melting, samples are from time to time taken through the pipe *U*.

Figs. 209 and 210 exhibit a plant for obtaining tallow from animal crude fat, constructed by W. Gellhorn, H. Flottmann & Co.

The crude fat to be melted is brought into the rendering kettle *A*, and rests upon a grate *B* covered with fine felt.

The rendering kettle is located in the basement, the neck projecting into the first story where all the other apparatuses are placed, much time in handling and charging being thus saved.

Fig. 209.



TALLOW-RENDERING PLANT.

Section through the rendering house.

A, rendering kettle; *B*, grate with filter; *C*, steam-boiler; *D*, steam-pipe; *E*, branch of *D* towards *A*; *F*, branch of *D* towards *A*; *G*, valve in *E*; *H*, valve in *F*; *J*, valve; *K*, conduit to condenser; *L*, valve in *K*; *M*, condenser; *N*, receiver; *O*, water-conduit; *P*, conduit for gases to the fire-box; *Q*, discharge-pipe; *R*, discharge-pipe; *S*, general discharge-pipe; *T*, man-hole; *U*, conduit from *A* to *W*, *V*, valve in *U*; *W*, clarifying back; *X*, conduit from *A* to *Y*; *Y*, clarifying kettle; *Z*, steam-conduit to *F*.

The rendering kettle is constructed of boiler-plate, and to prevent radiation of heat, surrounded by a sheet-iron jacket stuffed with slag-hair.

The rendering kettle, A, being filled with crude fat, sufficient water is added to cover the latter, and the neck closed steam-tight with a cover.

From the boiler *C* the pipe *D* conveys steam into the rendering house to above the kettle *A*, where it branches off vertically downward in two conduits *E* and *F*, the latter being provided with the valves *G* and *H*. The conduit *E* extends nearly to the bottom of the kettle *A*.

The rendering operation commences with opening the valve *G* on the conduit *E* and admitting steam of three atmospheres pressure beneath the grate *B* in the kettle *A*, whereby the water is brought to the boiling point and the crude fat melted.

The entire rendering process requires 5 hours; during this time the boilers must of course be several times fed, whereby the pressure of the steam is decreased. Now it might happen that this pressure is smaller than the pressure in the rendering kettle *A*, and the contents of the latter would be forced through the branch *E*, and the pipe *D* into the steam boiler *C*. To prevent this a valve *J* is inserted in the conduit *D*. To observe the pressure a manometer is also fixed in the conduit *D* and the rendering kettle *A*. In case of great differences in the pressure the valve *G* is closed.

After one hour the valve *G* is closed and the valve in the conduit *K* opened. Steam and the badly smelling gases evolved, together with globules of fat carried along from the rendering kettle *A*, pass into the condenser *M*, which, like the receiver *N* connected with it, is filled half full with cold water.

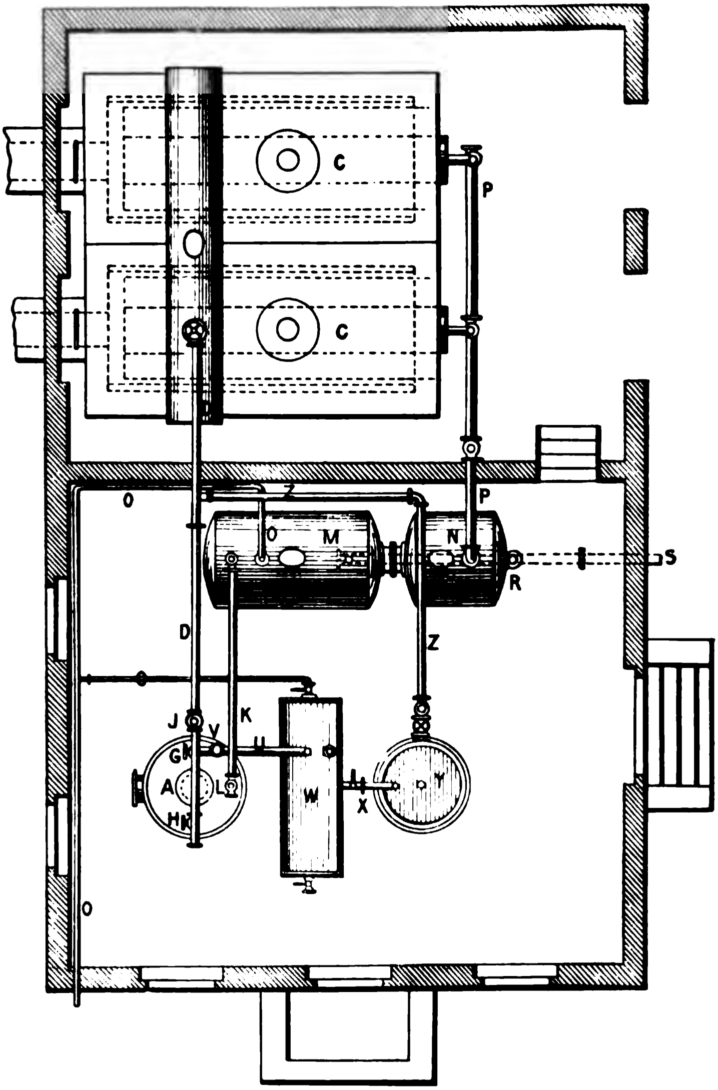
The pipe *K* is continued in the interior of the condenser and leads to below the level of the water.

Sufficient water to condense the steam and fix the badly-smelling gases on the water flows in through the conduit *K*.

The non-condensed gases pass together with the precipitated particles of fat and the heated water into the receiver *N*. The gases not remaining in the receiver pass through the conduit *P* behind the fire-bridge of the boiler, where they are burned.

To maintain the level of the water constant in the condenser

FIG. 210.



TALLOW-RENDERING PLANT. GROUND-PLAN.

M and the receiver *N*, the pipe *Q* bent downward in the receiver *N* carries off as much warm water as cold water flows in;

the warm water passes into the waste-pipe *R* and from there into the general discharge-pipe *S*, which leads to a place outside the building, where the water, etc. is mixed with earth; to be finally used as fertilizer.

The fat accumulating in time in the receiver *N* is occasionally removed through the man-hole *T*. For emptying and cleansing the condenser and receiver, discharge cocks leading to the conduit *S* are provided.

The condenser *M*, receiver *N* and the rendering kettle, are constructed of boiler-plate.

When the gas has been carried off, the admission of water to the condenser is interrupted and the rendering kettle *A* shut off from the condenser *M* by closing the valve *L*. Through the valve *G* fresh steam is now introduced into the rendering kettle *A*, and rendering of the crude fat continued for 4 hours. *G* is then closed, and the steam and gases conducted in the above-described manner to the condenser *M*.

If the manometer on the rendering kettle *A* indicates no more pressure, the kettle is shut off from all conduits and other apparatuses, and allowed to rest for one hour, whereby the first clarifying of the rendered fat from admixed solid residues and dirt takes place.

The valve *H* in the conduit *F* is then opened; steam now enters the kettle from above and presses upon the surface of the fat standing upon a layer of water. After opening the valve *V* the water and fat in the kettle *A* ascend through the pipe *E* and pass through the pipe *U* into the clarifying back *W*. The water flows in first, and finally the tallow freed from the coarsest dirt and the solid residues by the filter *B*. The residues are removed from *B* through the lower portion of the rendering kettle *A*, which must of course be closed steam-tight during the rendering operation.

The clarifying back of boiler plate should have as large a surface as possible, and serves for separating particles of dirt which either sink to the bottom, or form a thin layer on top.

The fat remains in the clarifying back *W* 6 to 8 hours, when it is lifted by water, admitted slowly through the conduit *O* until it runs off through the pipe *X*, provided with a cock, into the clarifying kettle *Y*. The dirt deposited in the clarifying back *W* and the water are discharged through a pipe provided with a cock.

The clarifying kettle *Y* is a double-walled wrought iron vessel capable of withstanding the same pressure—3 atmospheres—used in the rendering kettle *A*; to prevent radiation of heat it is provided with a sheet-iron jacket stuffed with slag-hair.

The clarifying kettle *Y* is partially filled with pure cold water. The fat is then admitted from the clarifying back *W*, and the whole heated to gentle boiling by conducting steam from the pipe *D* through the pipe *F* between the walls of the kettle.

After gently boiling for one hour, during which time the scum forming on the surface is from time to time removed, the valve in the conduit *Z* is closed, and the steam and condensed water conducted through the pipe *S* to a place outside the building.

When the mass in the clarifying kettle has cooled off so far that the fat commences to solidify, the water, and next the dirt, are discharged through a pipe projecting into the cellar. The pure fat is then drawn off into barrels for shipment.

During the warm season of the year cold water is admitted through the conduit *O* between the walls of the clarifying kettle *Y*, to accelerate the solidification of the fat.

With this apparatus perfectly pure tallow is obtained.

There are many other apparatuses of various construction, more or less well adapted for rendering tallow; but we will only mention two other methods, one relating to the rendering and the other to the disinfecting process.

1. Evrad's rendering method of treating the crude tallow with dilute solution of caustic soda, whereby the noisome fatty acids are fixed, has received less attention than it deserves. It requires oniy a temperature not exceeding 212°F. For the purpose, 100 parts by weight of tallow are mixed with the same quantity of a 1 to 1½ per cent. of soda lye and the mixture

heated by steam. The alkali causes the cell tissue to swell up; the fat floating on the surface is kept fluid for a few hours, whereby it clarifies, and is finally washed with water.

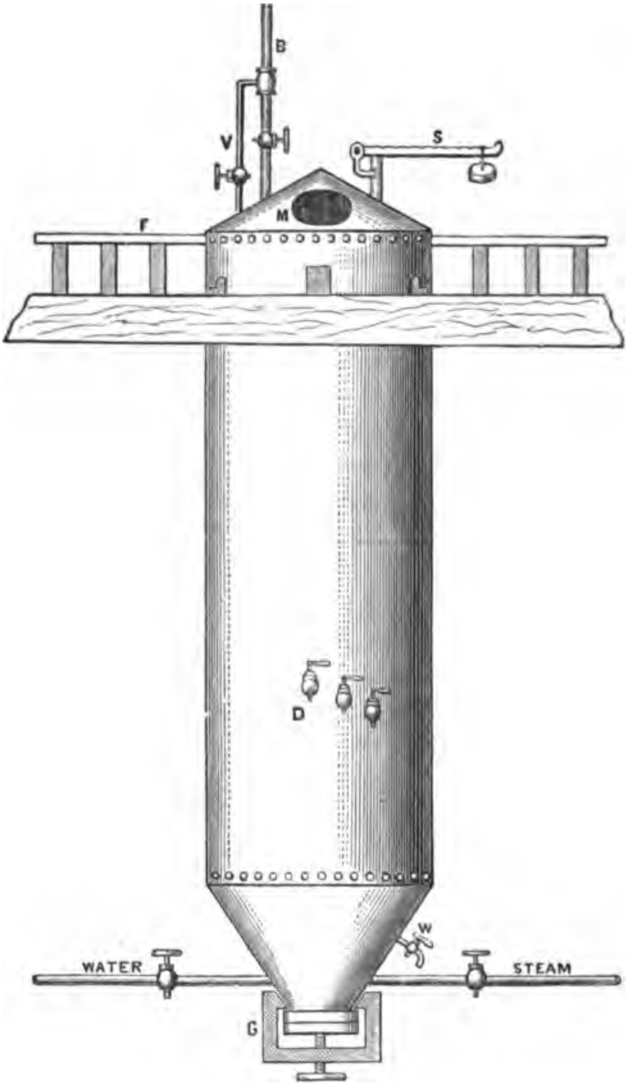
For old fat the method is, however, not suitable. Disagreeable vapors of ammonia are developed; on heating, the fat foams strongly and its separation from the emulsive lye is difficult.

2. According to Stein, boilers with a false perforated bottom, upon which the greaves remain so that they cannot be scorched, are provided with perforated lids covered with linen, upon which are placed alternate layers of lime and charcoal. The developed gases and vapors, it is claimed, are rendered inodorous by passing through these layers, which however must be renewed with every fresh charge of tallow.

Rendering lard.—The rendering of lard is connected with no inconveniences whatever, and is effected either over an open fire or by steam. The small quantity of lard made by butchers is usually "kettle-rendered," after the manner practiced by farmers in making lard for home consumption. The scraps are often saved up for a considerable time by the butchers before rendering, and that is likely to increase the free acid present. This lard is also frequently dark-colored, and contains a considerable quantity of glue.

Fig. 211 represents the type of apparatus used for rendering lard under pressure. The rendering vessel is made of boiler iron or steel, and varies in size according to the magnitude of the establishment. A very common size is 10 to 12 feet in length and 3 to 5 feet in diameter. The heads, scraps and other materials are put in at *M*. When the tank is full *M* is closed. Steam is admitted through the pipe, thus marked, and condensed water drawn off through the water pipe. Through the cocks at *D* the depth of lard in the tank can be determined and the lard drawn off. When the process is finished and the lard drawn off, the bottom *G* is opened and the "tankage" withdrawn and dried for fertilizing purposes.

FIG. 211.



LARD RENDERING APPARATUS.

Kinds of lard.—G. W. Wiley[*] classifies lard as follows: According to the parts of the fat used and the methods of rendering it, lard is divided into several classes. From material used the following classification may be made:

1. *Neutral lard* is composed of the fats derived from the leaf of the slaughtered animal, taken in a perfectly fresh state. The leaf is either chilled in a cold atmosphere or treated with cold water to remove the animal heat. It is then reduced to a pulp in a grinder and passed at once to the rendering kettle. The fat is rendered at a temperature of 105° to 120° F. Only a part of the lard is separated at this temperature, and the rest is sent to other rendering tanks to be made into another kind of product. The lard obtained as above is washed in a melted state with water containing a trace of sodium carbonate, sodium chloride, or a dilute acid. The lard thus formed is almost neutral, containing not to exceed 0.25 per cent. free acid; but it may contain a considerable quantity of water and some salt. This neutral lard is used almost exclusively for making butterine (oleomargarine).

2. *Leaf Lard.* The residue unrendered in the above process is subjected to steam-heat under pressure, and the fat thus obtained is called leaf-lard. Formerly this was the only kind of lard recognized by the Chicago Board of Trade, and was then made of the whole leaf.

3. *Choice kettle-rendered lard; choice lard.*—The quantity of lard required for butterine does not include all of the leaf produced. The remaining portions of the leaf, together with the fat cut from the backs, are rendered in steam-jacketed open kettles and produce a choice variety of lard known as "kettle-rendered." The hide is removed from the back fat before rendering, and both leaf and back fat are passed through a pulping machine before they enter the kettle. Choice lard is thus defined by the regulations of the Chicago Board of Trade:

"Choice lard to be made from leaf and trimmings only, either steam or kettle-rendered, the manner of rendering to be branded on each tierce."

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[*] U. S. Department of Agriculture, Division of Chemistry. Bulletin No. 13, Washington, 1889.

4. *Prime steam lard.*—The prime steam lard of commerce is made as follows: The whole head of the hog, after the removal of the jowl, is used for rendering. The heads are placed in the bottom of the rendering tank. The fat is pulled off the small intestines and also placed in the tank. Any fat that may be attached to the heart of the animal is also used. In houses where kettle-rendered lard is not made, the back fat and trimmings are also used. When there is no demand for leaf lard the leaf is also put into the rendering tank with the other portions of the body mentioned. It is thus seen that prime steam lard may be taken to represent the fat of the whole animal, or only portions thereof. The quantity of fat afforded by each animal varies with the market to which the meat is to be sent. A hog trimmed for the domestic market will give an average of about 40 pounds, while from one destined for the English market only about 20 pounds of lard will be made. Prime steam lard is thus defined by the Chicago Board of Trade:

"Standard prime steam lard shall be solely the product of the trimmings and other fat parts of the hogs rendered in tanks by direct application of steam, and without subsequent change in grain or character by the use of agitators or other machinery, except as such change may unavoidably come from transportation. It shall have proper color, flavor and soundness for keeping, and no material which has been salted shall be included. The name and location of the renderer and the grade of the lard shall be plainly branded on each package at the time of packing."

This lard is passed solely on inspection; the inspector having no authority to supervise rendering establishments in order to secure a proper control of the kettles. According to the printed regulations, any part of the hog containing fat can be legally used.

Since much uncertainty exists in regard to the disposition of the guts of the hog, H. W. Wiley has carefully investigated the subject and gives the results of his study as follows:

5. *Guts.*—The definition of the term as used by hog packers is: Everything inside of a hog except the lungs and heart, or, in other words, the abdominal viscera complete. The material is handled as follows:

When the hog is split open the viscera are separated by cutting out the portion of flesh surrounding the anus and taking a strip containing the external urino-generative organs. The whole viscera are thrown on a table and divided as follows: The heart is thrown to one side and the fatty portion trimmed off for lard. The rest goes into the offal tank or sausage. The liver and lungs goes into the offal tank (or sausage). The rectum and large intestines are pulled from the intestinal fat and peritoneum and, along with the adhering flesh and genito-urinary organs, sent to the trimmer. All flesh and the above-mentioned organs are trimmed off and the intestine proper is used for sausage casings. The trimmings, including the genito-urinary organs, are washed and dumped into the rendering tank. The small intestine is also pulled from the fatty membrane surrounding it and saved for sausage casings. The remaining material, consisting of the peritoneum, diaphragm, stomach, and adhering membranes, together with the intestinal fat, constitute the "guts" which are undergoing the process of washing, which is usually conducted in three or four different tanks. As the "guts" pass into the first tank the stomach and peritoneum are split open, and also any portions of the intestines which sometimes adhere to the peritoneum. After receiving a rough wash they are passed from tank to tank, when, after the third or fourth wash, they are ready for the rendering tank. The omentum fat is cut from the kidneys, and the kidneys with a little adhering fat go into the rendering tank. Spleen and pancreas go into the rendering tanks, as do also the trachea, vocal chords and œsophagus. To sum up, it is safe to say that everything goes into the rendering tank, with the following exceptions:

1. The intestines proper, which are saved for sausage casings.
2. The liver and lungs.
3. That part of the heart free from fat.

higher fusing point than the substances poor in oil, and having also a higher solidifying point, these properties are made use of for the separation of the solid from the fluid parts.

For this purpose the tallow in lots of 4500 to 6500 lbs. is melted in wooden tanks provided with steam-coils. The tanks are then closed carefully and allowed to stand 8 to 10 days in a room having a temperature of 32 to 36° F. below the melting point of the tallow. By this slow cooling the solid masses of fat crystallize in hard grains from the fluid portions and deposit in large conglomerate cauliflower-like masses on the bottoms and sides of the tanks. The clear fluid portion remains in the center of the tank and is drawn off through a cock. The crystalline mass when drained off is melted with water. On cooling, the melted crystalline mass solidifies to hard crystalline loaves which can be directly used for the manufacture of the better qualities of candles.

For *bleaching tallow* with chemicals, three methods are principally in use: 1, *with chromic acid;* 2, *with pyrolusite;* and 3, with *hypochlorites*, as follows:—

1. 220 pounds of the yellow-gray tallow to be bleached and melted with 2.2 pounds of sulphuric acid previously diluted with 1½ gallons of water; 1.1 pounds of powdered potassium dichromate added, and the whole gradually brought to the boiling point.

When cold the acid liquid is removed, and the tallow washed with water.

2. The treatment with pyrolusite is similar to the preceding. To 220 pounds of tallow add 2.11 pints of sulphuric acid, previously diluted with 7½ gallons of water; after melting add 2.2 pounds of powdered pyrolusite.

The mass becomes gradually black, then bluish, and finally white, when the tallow is washed.

3. For bleaching with hypochlorites melt 220 pounds of tallow with 2.2 pounds of soda, dissolved in 2¾ gallons of water, then add a clear solution of 3.3 pounds of chloride of lime in 7 gallons of water, heat to the boiling point, and gradu-

ally and carefully add a slight excess of dilute sulphuric acid. The mass is then allowed to rest, and finally washed.

In the last mode of bleaching, a combination of chlorine with glycerin—chlorhydrin—is sometimes formed, which volatilizes with the steam. It has an irritating effect upon the mucous membranes, and the manipulation should therefore be carried on under a well-drawing chimney.

It frequently happens that to give tallow a better appearance, indigo, Prussian blue, and especially blue aniline colors, are added. The methods for detecting these substances will be found under "Tallow."

CHAPTER XV.

DESCRIPTIONS, PROPERTIES, ADULTERATIONS, ETC., OF OILS AND FATS.

1. *Glycerides of Oleic Acid, or Non-drying Oils.*

A. OILS OF THE VEGETABLE KINGDOM.

Minnoseæ (*Leguminosæ*).

Pentraclethra macrophylla, Benth. The seed of this plant comes from the west coast of Africa, where it is known under the various names of "*Owala*," "*Opochala*," and "*Nulla pansa*." The cotyledons contain 48 to 49 per cent. of oil, which is utilized as table oil, for lubricating purposes, and in the manufacture of soap.

Pithecolobium dulce, Benth., is indigenous to the Philippine Islands, where it is known as "*Coorookoopilly*." The black shiny seed inclosed in an aril furnishes an oil of the consistency and nature of castor oil.

Parakia biglandulosa, Br., called in the East Indies "*Igna*." It contains 18 per cent. of oil.

Ædenanthera pavonina, Linn., which is known in tropical India as "*Kuchandana*," contains about 35 per cent. of oil.

Entada scandens, Benth. The seed of this plant, known in Bengal and Ceylon as "*Gilla*," and in Madagascar as "*corial vegetal*," yields about 30 per cent. of oil.

Caesalpiniaceæ (*Leguminosæ*).

1. *Peanut oil, earthnut oil, ground oil, arachis oil, (oleum arachidis, Erdeichel oel*, G.[*]; *huile de pistache de terre*, F[†].*)*

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[*] German.

[†] French.

This oil is obtained from the peanut, the fruit of *Arachis hypogaea*, Linn., known also in different localities as the earthnut, groundnut, ground pea, goobar and pindar. The plant is a trailing, straggling annual, growing from 1 to 2 feet high, with thick, angular, pale green, hairy stems, and spreading branches, and has the peculiar habit of maturing its fruit underground. Strictly speaking it is not a nut at all, and should more properly be called the ground pea. Its blossom is at the end of a long, pedicle-like calyx tube, the ovary being at the base. After the fall of the flower, the peduncle or "spike" elongates and bends downward, pushing several inches into the ground, where the ovary at its extremity begins to enlarge and develops into a pale yellowish, wrinkled, slightly curved pod, often contracted in the middle, containg from one to three seeds. Should the "spike" by accident not be enabled to thrust its point in the ground, within a few hours after the fall of the flower it withers and dies.

Like many other extensively cultivated plants, the peanut has not been found in a truly wild state, and hence it is difficult to fix upon its habitat. So widely has it been cultivated in eastern countries that some botanists have attempted to trace its spread from China to Japan, thence through the East India Islands to India, and thence to Africa, where in the seventeenth century it was so extensively cultivated and had become such an important article of native food that the slave dealers loaded their vessels with it, using it as food for their cargoes of captives. But the weight of authority seems to be in favor of accepting it as a native of Brazil, thus adding the peanut to the four other plants of commercial importance that America has contributed to the agriculture of the world, namely, cotton, Indian corn, potato, and tobacco. Though it may be a native of the Western Continent, it early became a largely cultivated plant in the warmer portions of the Old World, occupying a distinct place in the agriculture of those countries long before its merits were recognized in the land of its origin.

Since Jaubert, in 1840, brought the first peanuts from the

Cape Verd Islands to Marseilles, and it was found that in the case of dearth of olives, the oil pressed from them might compete with olive oil, the plant has been cultivated on the West coast of Africa—Congo, Senegal, in the Niam and Mombattu countries in the interior of Africa, and in East Africa; in the East Indies—Madras, Calcutta; in Java, Sumatra, etc., in the southern portions of the United States, as well as in Southern Europe—Italy, Spain, and France.

There are several varieties of peanuts: red, white and brown. The varieties chiefly cultivated in the United States are the Virginia, running and bunch; the Tennessee and Georgia, white and red; the North Carolina and the Spanish. The Virginia varieties, being most widely known and popular with the trade, are the ones commonly planted. There is little difference between the Virginia and Tennessee nuts, being sold as "Virginia hand-picked" peanuts. In Costa Rica there is a variety with long pods without division, containing four or five seeds, and in the Argentine Republic a large sized variety, with a deep orange-colored shell. In the Malay Archipelago there are two varieties, called the white and brown, resembling probably the white and red Tennessee varieties except as to size. The peanut of Africa and India resembles the North Carolina variety in size, and is raised principally for the oil which is contained in its kernels.

The Spanish nut has a small kernel of fine quality, and is in demand as "confectioners' stock," being worth several cents per pound more than any other shelled stock.

In harvesting peanuts great care has to be taken, since the fruit of plants not entirely "dead," *i. e.*, ripe, does not keep well and yields less oil. The nuts should be out of the ground before the first frost, as it is injurious both to the vines, when regarded as fodder, and to the kernels.

In this country peanut farmers in harvesting the crop use a plow made especially for the purpose, without a mold board, and with a "sword," or long cutting flanges welded to the point. The plow is passed down each side of the row, and deep enough to sever the tap root without disturbing the pods. The vines are then lifted from the ground with pitchforks, and placed in rows; they are afterwards stacked around short poles. Two weeks later the pods should be dry enough to be picked off. After picking, which is generally done by women and children, the nuts are placed in bags, holding four bushels, and either stored away in dry, well-ventilated sheds, or at once sold to the "factories" where they are cleaned, sorted, sacked and branded.

Since the establishment of "peanut factories" or "recleaners" in nearly every community in which much attention is paid to this crop, the planter has ceased to especially prepare his nuts for market, selling them as "farmers' stock" to those factories or recleaners, where they are subjected to a treatment of fanning, polishing and sorting before being put upon the market.

The machinery, neither costly nor intricate, is placed in a four-story building in such a way that the peanuts are not handled from the time they are put in their uncleaned condition in the hoppers on the fourth floor until on the first floor they are sewed in bags, branded, and marked ready for shipment, with the exception that in the course of this process they have passed over a movable table in the form of an endless belt between two rows of operators somewhat skilled in the detection of immature and faulty nuts, which are picked out and put into a separate receptacle, only the good and merchantable nuts being allowed to pass into the bag beneath; these are the hand-picked "factory stock" of the trade.*

Picking the nuts from the vine by hand being slow and tedious work, and one of the largest items of expense to the peanut farmer, Underwood's peanut-picker (Fig. 212) is used for this purpose in some sections of the United States, especially in the Wilmington, N. C., section. The variety of peanut raised there being much smaller than the Virginia or Tennessee nut, and also more completely filling the shell, is not so easily injured as the larger varieties, and thus can be picked by machinery. Underwood's picker is of the nature of a thrashing machine, and, of course, tears off both the ripe and unripe nuts, which is avoided by hand-picking. When worked by hand the capacity of the machine is about 660 lbs. per day, and when driven by a motor up to 2000 lbs.

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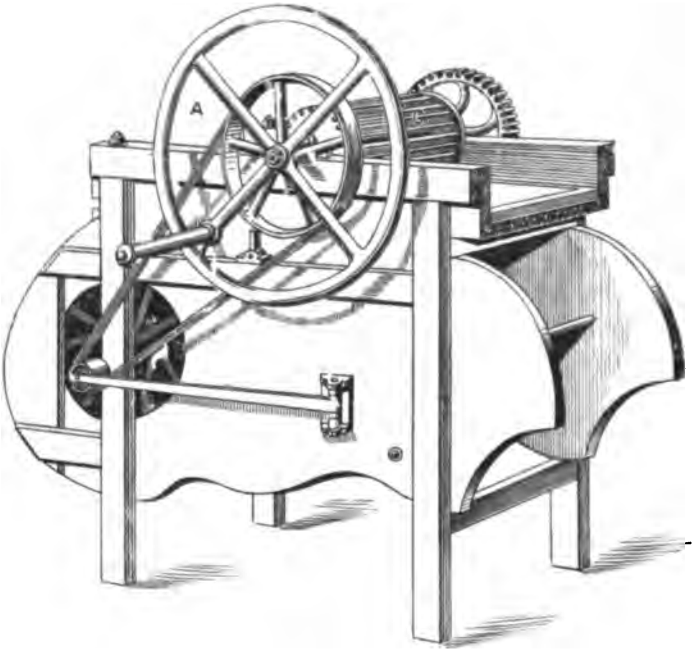
* **Peanuts: Culture and Uses, by R. B. Handy, Washington, 1895.**

FIG. 212.



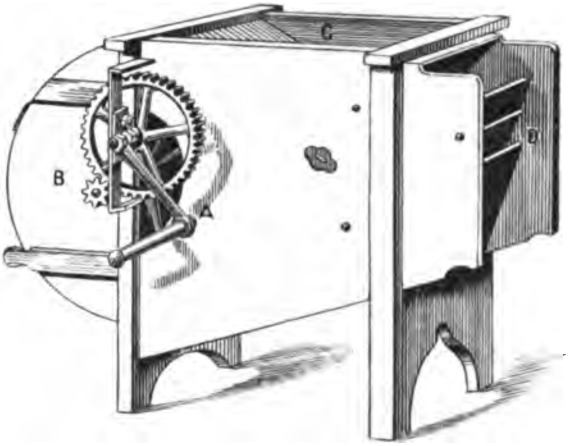
UNDERWOOD'S PEA-NUT PICKER.

A, crank; *B*, frame; *C*, drum.

The mixture of ripe and unripe nuts being of less value, it is passed through a separator, Crocker's machine, Fig. 213, being frequently used for this purpose. It separates the nuts into three grades; the unripe nuts being the heaviest, fall into a separate apartment.

With the attendance of four men, the machine sorts 17,500 to 22,000 lbs. of nuts per day. In the absence of such a separator a fan is frequently used, which however separates only the empty shells.

FIG. 213.



CROCKER'S PEANUT-SEPARATOR.

A, crank; *B*, drum; *C*, frame; *D*. box.

As a rule, peanuts are brought into commerce unshelled, so that the planter has nothing to do with this work. For soap-oil the nuts are frequently worked without being shelled; the shell of older nuts is readily rubbed off by sieves or in a fan. A hand-peanut-sheller is shown in Fig. 214.

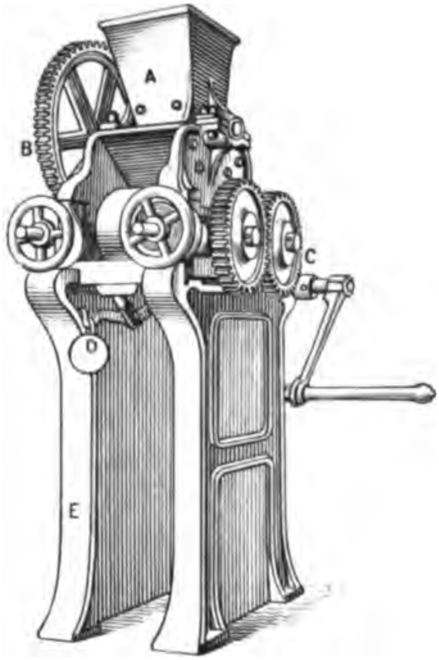
The shells amount to about 1 per cent by weight.

The oil occurs in parenchymatous cells of the cotyledons and amounts to 38, and at the utmost to 50 per cent. of the nuts. The composition of the nuts is as follows:

	Fresh nuts.		Older nuts.	
Oil	37.84 p. c.		41.63 p. c.	
Organic substances	52.36 "		53.12 "	
albumen therein		27.25 p. c.		27.25 p. c.
Ash	2.43 "		2.50 "	
Water	7.37 "		2.75 "	
	100.00		100.00	

The oil is extracted by pressure. The first cold-drawn oil is

FIG. 214.



A, hopper; *B*, cog-wheel; *C*, crank; *D*, weight; *E*, frame.

nearly colorless and of an agreeable taste, and is used as fine table oil. The comminuted seeds are then sprinkled with water and subjected to a second pressure, which yields an oil also fit for table use, but chiefly employed for illuminating purposes. The residue is subjected to a third warm pressure, and yields an oil of a yellowish color and less agreeable taste and odor. It is used in the manufacture of soaps and lubricants.

The most important secondary production of the peanut oil manufacture is the oil-cake or meal, which remains after the oil has been extracted. This sells for from $30 to $33 per ton in Germany, where it is used for feeding cattle and sheep. A recent analysis of peanut cake furnished by an oil factory in Tennessee gave the following results: Water, 6.58 per cent.; ash, 4.21 per cent.; protein, 53.19 per cent.; fiber, 3.75 per cent.; nitrogen-free extract, 24.01 per cent.; and fat, 53.19 per cent.

Dietrich and König give the average coefficient of digestibility of peanut cake as follows: Protein, 90.24; fats, 85.66; nitrogen-free extract, 92.87.

The yearly production of peanuts in this country is about 4,000,000 bushels of 22 pounds, Virginia, Georgia, Tennessee and North Carolina being, according to the Eleventh Census, the largest producers in the order named. These 4,000,000 bushels, whilst fully supplying the present demand in the United States, constitute but a small portion of the peanut crop of the world, as the exportation from Africa and India to Europe, in 1892, amounted to nearly 400,000,000 pounds, Marseilles taking 222,000,000 pounds, most of which were converted into oil.* The peanut crop of the world may be safely estimated at least at 600,000,000 pounds. Peanut oil is a perfect type of a non-drying oil. It is largely used by perfumers in the manufacture of pomades, cold cream, etc.

The specific gravity of the finest fresh oil is 0.918 at 59° F., and that of the old oil 0.9202. It is more limpid than olive oil, becomes turbid at 37.4° F., congeals at 26.5° to 25° F., and solidifies entirely at 19° F.

Peannt oil consists of the glycerides of palmitic, hypogæic, oleic, and arachidic acids. The latter acid, first prepared from peanut oil by Gössmann, crystallizes in small shining scales, melts at 167° F. and solidifies again at 164.3° F. to a radiated crystalline mass. Arachidic acid occurs also in the fat of the fruit of *Nephelium lappaceum*, Linn., in cacao-butter, and is identical with *butic acid* prepared by Heintz from butter.

Peanut oil is sparingly soluble in alcohol—100 parts 90 per cent alcohol, dissolve 0.52 part oil—but readily in either, chloroform and oil of turpentine. It is durable and burns with a very good flame. It saponifies slowly, but yields an excellent, firm, whitish soap, free from odor. It forms at present the chief constituent of Marseilles (castile) soap.

Nitric acid containing hyponitric acid and of specific gravity

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* This large exportation from India has been greatly stimulated by the depreciation of silver—this constituting a bounty of 100 per cent. on this export.—H. C. B.

1.300, colors the oil reddish yellow, and does not solidify it in 24 hours. By adding to the mixture starch or copper filings for the development of nitrous acid, it turns pale and solidifies in about 24 hours, the hypogæic acid being converted into the isomeric gaëdic acid.

By carefully pouring *fuming nitric acid* into a test-tube containing peanut oil, so that the fluids do not mix, a brownish color is first produced on the point of contact, which soon changes into a narrow, pale green, and a broad, zone of an intense cherry color. In about ten minutes a dull, pale-green zone remains. By shaking the oil with the acid a reddish-yellow coloration takes place.

By adding drop by drop 3 drops of *sulphuric acid* of 66° B. to 20 drops of peanut oil, the latter turns grayish-yellow, and, on shaking, becomes first brownish yellow and finally brown.

One volume of *soda or potash lye* of 1.330 specific gravity, mixed with 5 volumes of oil, gives a yellow, flesh-colored mixture which quickly becomes thick and by heating acquires a lighter color.

Saponfication number	194 - 196
Iodine number of the oil	94 - 96
" " " fatty acids	96 - 97
Fusing point of the fatty acids	78.8°- 80.6°F.
Solidifying point of the fatty acids	77° - 73.4°F.

Considerable quantities of peanut oil are brought to England from the East Indies, especially from Madras. But little oil is sent from England and France to Germany; however, the importation of peanuts from the East Indies—Madras and Calcutta—as well as from the coast of West Africa, the French colonies on the Congo and the Senegal, and from Algiers, is immense and steadily increasing.

The principal trade is by way of Marseilles, London, Liverpool, and Rotterdam. From the coast of West Africa alone 77,000 to 85,000 tons of peanuts are shipped, chiefly to Marseilles, where most of the peanut oil is expressed and used in the manufacture of Marseilles (castile) soap.

Regarding the quantities of peanuts worked for oil in the United States, no statistics could be obtained.

2. *Ben oil* or *soringa oil* (*oleum balaninum; Bihenöl*, G., *huilede ben*, F.).—This oil is obtained from the seed of various species of *Moringa*, trees indigenous to Egypt, Arabia, Syria, and the East Indies, and cultivated in tropical America. The seed contains from 30 to 35 per cent. of oil, which, when carefully expressed, is white or of a slightly yellowish color, and possesses an agreeable sweetish flavor. In the West Indies it is used as a salad oil. The oil expressed last has a darker color, an acrid, somewhat pungent taste, and purging properties.

The oil is neutral and keeps long in the air without growing rank. Its specific gravity is 0.912 at 59° F. At 77° to 68° F. it is limpid, somewhat viscous at 59° F., and below that becomes turbid. On cooling to 44.5° F. crystals commence to separate and the oil divides into two parts, one solid, consisting of stearin, palmitin, etc., and the other fluid, of olein.

Ben oil is completely saponified with potash lye, and besides glycerin, the alkaline salts of stearic, palmitic, myristic, oleic, and benic acids are formed. To the latter the term *moringic acid* was applied by Walter, and corresponds completely to oleic acid. Walter's behenic acid = benimargaric acid $\left.\begin{matrix}C_{15}H_{29}O\\H\end{matrix}\right\}O$ is, according to Heintz, a mixture of 75 parts palmitic acid with 25 parts myristic acid, and melts at 125.6° to 131° F.

Benic, behenic or benistearic acid = $\left.\begin{matrix}C_{22}H_{43}O\\H\end{matrix}\right\}O$ of Völker is a white crystalline fat melting at 168.8° F. and solidifying at 158° F. It is soluble in boiling alcohol, crystallizing from it in acicular crystals.

Besides as a salad oil, ben oil is used for various purposes, as an embrocation for the skin, especially in the Orient, for perfumery, toilet soaps and hair oils.

Owing to its power of retaining odors and not becoming rancid, even after many years, it is highly valued for the extraction of aromatic substances, which on account of their extremely delicate constitution would become more or less decomposed by other methods, for instance, violet oil, jasmine oil, the oil from the flowers of *Polyanthes tuberosa*, etc.

The portion of the oil remaining fluid at 44.5° F. is used for lubricating of machinery and clocks.

Ben oil was formerly exported from the East and West Indies, but is now almost entirely consumed in the countries of its origin, very little of it reaching England and France, and none of it the rest of the Continent of Europe.

3. *Bonduc nut oil or fever nut oil* (*Bonducnussöl*, G.) is obtained from the seeds of *Cæsalpinia Bonducella*, Roxb., a large climbing bush indigenous to the eastern parts of tropic Asia, Africa, and America. The oil is used for illuminating purposes and as an embrocation for rheumatism. The seed, also called "nicker seed" has a diameter of ½ to ¾ inch.

4. *Cæsalpinia digyna*, Wall. = *Cæsalpinia oleosperma*, Roxb.

5. *Tonka-bean oil* (*Tonkabohnenöl*, G.; *huile de fève de Tonkin*, F.) is obtained from the seed of *Dipterix odorata*, Willd., a tree indigenous to Guiana. The seed yields about 25 per cent. of a nearly colorless oil holding cumarin in solution. It is principally used for perfumery purposes.

6. *Tamarind oil.*—The seeds of the tamarind tree (*Tamarindus indica*, Linn.) contain 20 per cent. of a viscous oil, with an odor of linseed oil, which is used for illuminating purposes.

7. *Bauhinia variegata*, L., and *Bauhinia candida*, Roxb., with 30 per cent. of oil.

Papilionaceæ (Leguminosæ).

1. *Dolichas Soja*, Linn. = *Soja japonica*, *Soja hispida* or *Chinese oil bean*, indigenous to Japan and China, and cultivated in southern Asia, The seed has a pungent taste and is used for food, while the oil, *soja bean oil*, incorrectly called *huile de pois*, pressed from it serves as a salad oil.

The soja bean contains according to Meissl and Boecker: Water, 10 per cent., soluble casein 30, albumen 0.5, insoluble casein 7, *fat* 18, cholesterin, lecithin, resin, wax, 2, dextrin 10.

The content of starch is dependent, according to O. Harz, on the degree of ripeness of the beans, thoroughly ripe beans containing but little starch.

The portion of the bean soluble in ether consists of 90 to 95 per cent. neutral fat and 5 to 10 per cent. cholesterin, lecethin, wax and resin.

2. *Butea frondosa*, Roxb., indigenous to India, yields a yellowish, somewhat thickish oil, known as *Dhak-kino-tree oil* or *Palas-tree oil*, which has a specific gravity of 0.927, and solidifies at 50° F.

3. The seed of *Pongamia glabra*, Vent., a tree indigenous to the East Indies, gives a quite thick, dark-yellow oil, known as *Korung oil*, which separates stearin at 43.0° to 46.5° F. Its specific gravity is 0.945. It is used for illuminating, and also medicinally, in India, for skin disease and rheumatism.

Amygdaleæ (Rosifloræ).

1. Almond oil (*oleum amygdalarum; Mandelöl* G.; *huile d' Amandes*, F.), is obtained by pressure, both from sweet and bitter almonds, the fruits of *Amygdalus communis*, Linn.

Sweet almonds are divided into two varieties, viz., hard-shelled, and soft-shelled or paper-shelled almonds, the latter variety being the product of *Amygdalus fragilis* Bork, and are exported, without being shelled, from Valencia and the Mediterranean ports of France and Italy. Hard-shelled almonds are generally shelled before being brought into commerce. The best varieties of sweet almonds are the Valencia almonds; they are large, full, very sweet and of agreeable taste; ambrosia almonds from Sicily, Girjenti, etc.; Provence almonds from Provence, Languedoc. The cheapest variety are the Barbary almonds, which contain many broken and bitter particles, and are small and unsightly in appearance. They are brought into market, generally by way of London, from Barbary and Mogador in Morocco.

Sweet almonds yield more fat oil than the bitter variety, they containing from 45 to 55 per cent. Their composition is as follows:

	Almonds 1 year old.	Almonds 4 years old.
Oil	51.42 p. c.	53.30 p. c.
Organic substances	38.19 "	39.24 "
albuminous substances therein	22.5 p. c.	23.00 p. c.
Ash	2.86 "	3.70 "
Water	9.53 "	3.76 "
	100.00 "	100.00 "

The ash of sweet almonds contains

Potash	27.95 per cent.
Soda	0.23 "
Magnesia	17.66 "
Lime	8.81 "
Ferric oxide	0.55 "
Chlorine	—
Sulphuric acid	0.37 "
Silica	—
Phosphoric acid	43.63 "
	100.00 "

Among the organic substances are found gum-like bodies (3 per cent.), grape sugar (6 per cent.), and *emulsin* or *synaptase*. Starch is entirely wanting in sweet as well as bitter almonds. Emulsin is the specific ferment of bitter almonds, from which it is obtaine by exhausting the powdered paste from which the oil has been expressed, with cold water, adding acetic acid to the solution to remove proteids, and precipitating the emulsin with alcohol, It is a white friable mass soluble in water, but insoluble in spirit of wine.

Most of the bitter almonds are brought into commerce from North Africa, Tripoli, Morocco, Algiers, Teneriffe, and southern France. The large Sicilian almonds are highly valued.

The constituents of bitter almonds vary very much and also their content of oil.

Their average composition is as follows:

Oil	42.80 p. c.	
Organic substances	48.50 "	
albuminous substances (emulsin, conglutin) therein		32.16 p. c.
Amygdalin		2.20 "
Ash	3.20 "	
Water	5.50 "	
	100.00 "	

Amygdalin $C_{20}H_{27}NO_{11}$ belongs to the glucoside series, and is a neutral substance of a somewhat bitter taste. To prepare it, a paste of bitter almonds, from which the oil has been expressed, is exhausted with boiling alcohol, the solution concentrated, and the amygdalin precipitated by adding ether. It is thus obtained in pearly scales, crystallizing from water in transparent prisms with three molecules of water. It is soluble in water and spirit of wine, but insoluble in ether. Brought in contact with emulsin and a sufficient quantity of water, it forms prussic acid, volatile bitter almond oil, and sugar.

$$\underset{\text{Amygdalin}}{C_{20}H_{27}NO_{11}} + \underset{\text{Water}}{2H_2O} = \underset{\text{Sugar}}{2C_6H_{12}O_6} + \underset{\text{Prussic acid}}{HCN} + \underset{\text{Bitter almond oil.}}{C_7H_5OH.}$$

This decomposition begins already in chewing bitter almonds, but is also effected by diluted acid and alkalies.

Pure amygdalin also decomposes, although in a less degree, the albumin of poppy seeds, hemp, and mustard seeds.

From the above conversion of the amygdalin with the emulsin, it will be seen that no water should be added in comminuting and pressing bitter almonds.

To obtain the oil, the almonds are first freed from dust by shaking in a sieve, and, after removing the broken almonds, which are always more or less rancid, comminuted in a mortar or in some other suitable manner. The paste thus obtained is packed in strong linen bags and pressed.

Generally sweet and bitter almonds mixed are used for pressing, but if the residue is to be utilized for the preparation of bitter almond water (*aqua amygdalarum*) and oil (*oleum amygdalarum æthereum*), only bitter almonds are used. If, however, the residue is to be utilized for cosmetics, the almonds are first peeled, soaked in cold water six to eight hours. and, after drying at not more than 77°F., comminuted and pressed.

Oil from peeled almonds changes in quality, has a tendency to become rancid, and is therefore of less value.

The comminuted almonds are twice pressed cold; for the third pressure, which gives an oil of less value, the broken pieces can be utilized, and the press-plates heated.

By pressure sweet almonds yield on an average 45 per cent. of oil, and bitter almonds 38 per cent.

The oil, after settling for eight days in well-stoppered bottles, is filtered and kept in small vessels.

The extracting process with canadol or ether can be advantageously employed.

There is no essential difference between the fixed oil of sweet almonds and that of bitter almonds; the latter has a greater tendency to become rancid. Both oils have the same value and are used for the same purposes.

Their average elementary composition is, according to Lefort, as follows:

	Oils of sweet almonds.	Oils of bitter almonds.
Carbon	70.48 p. c.	70.53 p. c.
Hydrogen	10.64 "	10.61 "
Oxygen	18.88 "	18.86 "
	100.00	100.00 "

Almond oil is clear and odorless, has a pale yellow color, and a very agreeable, mild taste. If it shows the taste or odor of essential bitter almond oil, water has been used in comminuting or pressing the bitter almonds, or the mixture of sweet and bitter almonds.

Almond oil is more viscous than poppy-seed oil, but more limpid than olive oil; at 14° F. it becomes thick, at 3.2° F. it assumes a white turbidity, and at —4° F. it solidifies to a white butter.

Its specific gravity at 68° F. is 0.917, and at 59° F., 0.919.

Its expanding capacity is nearly as large as that of olive oil, 100 cubic centimeters at 32° F. expanding to 101.6 cubic centimeters at 68° F.

Exposed to the air it readily turns rancid, and acquires a disagreeable taste and odor, and higher specific gravity. It is soluble in 60 parts of cold and 15 parts of boiling alcohol; at 68° F. 10 volumes of oil absorb 0.60 volume of absolute alcohol. On shaking equal volumes of oil and alcohol, the coloring matter of the oil, together with a portion of the oil, passes into the alcoholic solution; the oil becoming decolorized and acquires a pale orange color. It mixes in all proportions with ether, chloroform, etc., and fat oils.

Almond oil consists chiefly of pure olein; lead plaster prepared with it dissolves almost completely as lead oleate, while only traces of the lead salts of solid fatty acids remain.

The oil shaken with an equal volume of *nitric acid* gives at first a whitish mixture, which in about five minutes turns reddish yellow. By adding to this mixture copper or starch for the development of nitrous acid, the behavior of the oil from sweet almond, varies somewhat from that of bitter almonds, the first solidifying to a white mass in eight to twelve hours, and the latter only to a semi-solid mass in twenty-four hours.

By carefully adding *fuming nitric acid* to the oil in a test-tube, first a reddish, and then a green zone is formed. In scarcely one minute violent reaction with strong foaming takes place.

Three drops of *sulphuric acid* added to 20 drops of the oil produce first a yellow turbidity, which shortly becomes green yellow, and later on brownish-olive green, the oil becoming thick at the same time.

Glacial acetic acid mixed with the same volume of almond oil, dissolves the latter to a clear fluid only at 230° F.

Of *iodine* up to 57 per cent. is dissolved by almond oil.

One volume of *potash lye* or of *ammonia* shaken with five volumes of oil gives a grayish-white emulsion.

Almond oil is frequently adulterated with peach oil, poppy-seed oil, teel oil, nut oil. The simplest test is by the taste, as every admixture produces a peculiar flavor not characteristic of almond oil, poppy-seed oil especially leaving a certain sharpness behind. Adulterations with poppy-seed oil, etc., will also increase the specific gravity to above 0.919, and solidification takes place below —4° F.

According to Fehling, 50 grammes of almond oil mixed with 10 cubic centimeters sulphuric acid produce an increase in the temperature of 53.5° C., and the same quantities of poppy-seed oil and acid one of 74.5° C.; hence a higher temperature than 53.5° C. would be proof of adulteration.

A cooled mixture of equal parts of *concentrated sulphuric acid*, *red fuming nitric acid*, and water mixed with the oil in the proportion of 1 : 5 gives, according to Bieber, with

Pure almond oil a slightly yellowish-white emulsion, which later on passes into a reddish shade.

Peach oil is immediately colored peach-blossom red, and later on dark orange.

Sesamé oil turns pale yellowish-red, then dirty orange-red.

Poppy-seed oil and nut oil from walnuts give a somewhat whiter emulsion than almond oil.

From the difference in color the adulteration can readily be recognized.

Solution of subacetate of lead (*Goulard's extract*) shaken with an equal volume of almond oil, produces gray watery white turbidity, while an addition of other oils gives yellowish turbidities.

It is extremely difficult to establish by means of chemical reaction adulterations of almond oil with other oils, such as peanut, apricot kernel, sesamé oils, etc. Toward the elaïdin test, the behavior of genuine almond oils also varies so much as to render it impossible to come to a definite conclusion.

Better results are obtained by the determination of the acid number, saponification number and iodine number.

Acid number	204–205
Saponification number	194–196
Iodine number of the oils	82–83
Iodine number of the fatty acids	87–89
Fusing point of the fatty acids	57.2° F.
Solidifying point of the fatty acids	41 ° F.

Almond oil is used for perfumery purposes, in the manufacture of soap—it yields a very firm soap—and in medicine, especially in the form of emulsions, in inflammations ofthe digestive and respiratory passages.

Actual almond oil under the name of "sweet almond oil," is produced on a large scale only in England, mostly from the North African bitter almonds, further, from almonds brought from Bombay and other Indian territories. Genuine English almond oil is brought into commerce in barrels of 600 lbs. weight.

In Germany no more almond oil is produced than is necessary to obtain sufficient residue for the fabrication of almond water, amygdalin and partially of almond meal.

In Italy and Southern France, but little genuine almond oil is produced, the considerably cheaper peach kernel oil being chiefly expressed from the peach kernels imported on a large scale from the Levant. It forms mainly the product found in commerce under the name of "sweet almond oil" and is shipped in casks of various sizes, and from Southern France also in tin canisters.

2. *Peach kernel oil (oleum persicorum; Pfirsichkernöl*, G.; *huile de peche*, F.), is pressed from the kernels of the peach, *Amygdalus Persica*, L. The kernels are bitter, and, like bitter almonds, contain, besides emulsin, amygdalin, and can therefore be substituted for bitter almonds in the preparation of bitter-almond water and essential bitter-almond oil. In comminuting and pressing, no water can be used, for the same reason as mentioned under bitter almonds. The yield obtained is about 30 per cent.; the residue is used for a liqueur called "Persico."

Peach oil is clear and limpid, has a somewhat yellow color, and in taste and odor resembles almond oil.

At 16° to 14° F. it becomes thick, and solidifies at —0.4° F. Its specific gravity at 68° F. is 0.916, and at 59° F. 0.915. It contains, besides olein, somewhat more stearin and palmitin. Its behavior towards nitric acid resembles that of almond oil, only the coloring is more reddish. The first effect of sulphuric acid is also the same as on almond oil, but the final reaction—olive brown in the latter—is more brown in peach oil. The most characteristic test is the action of the mixture of concentrated sulphuric acid and red fuming nitric acid (see page 211), which immediately produces a peach-blossom red coloring.

3. *Apricot kernel oil* or *Himalaya apricot oil (oleum armeniaceae; Aprikosenöl* or *Marmottöl*, G.; *huile d' abricotier de Briancon*, or *huile de marmotte*, F.), is obtained from the kernels of the apricot (*Armeniaca vulgaris*, Linn.), which contain from 40 to 50 per cent. of oil. The apricot derived from Armenia is an intermediary link between the peach and prune. In Greece it is widely distributed, being there a common and excellent fruit. The stones, together with the kernels, are crushed and the obtained mass pressed, partly with the assistance of water and partly with that of heat. The residue is used for chicken feed or for a liqueur called " ratafia."

The oil, when purified by settling, is clear and bright and almost colorless, but turns yellow with age. It has a mild and agreeable taste, and an odor resembling that of bitter-almond oil. Its specific gravity is 0.915 at 59° F., and it solidifies at 7.0° F. It has great tendency to become rancid. It is used for a table oil, illuminating and perfumery purposes.

Saponification number	192.9.
Iodine number	100.
Fusing point of the fatty acids	40° F.
Solidifying point of the fatty acids	32° F.

4. *Prune-kernel oil.*—The kernels of the plum, *Prunus domestica*, L., contain 25 to 30 per cent, of oil, of which about 20 per

cent. are obtained by pressure. The oil is clear, has a yellowish color, and an agreeable almond-like odor and taste. It thickens at 39.0° F., and solidfies to a white mass at 16.25° F. Its specific gravity is 0.9127 at 59° F. It is used as a table oil and for illuminating.

5. *Cherry-kernel oil.*—The kernels of the cherry, *Prunus Cerasus*, Linn., contain 25 to 30 per cent. of a golden-yellow oil of a mild and agreeable flavor and 0.923 specific gravity at 59° F. The oil becomes thickish at 32° F., and solidifies at —2.2° to —4° F.

In Wuertemberg and the valleys of the Alps the cold-drawn oil is used for a table oil, and the warm-pressed for illuminating and in the manufacture of soap.

Pomaceæ (*Rosifloræ*).

1. *Apple-seed oil*, from the seed of the apple, *Pyrus malus*, Linn.

2. *Pear-seed oil*, from the seed of the pear, *Pyrus communis*, Linn.

The parenchymatous cells of the cotyledons of both fruits contain 12 to 15 per cent. of a pale-yellow fat oil of a very mild and agreeable flavor. It is used in Thuringia as a table oil and for illuminating.

3. *Quince-seed oil.*—Beside a large amount of mucus, the seed of the quince, *Pyrus cydonia*, Linn., contains 15 per cent. of a very mild oil.

Chrysobalaneæ (*Rosifloræ*).

1. *Chrysobalanus icoca*, Linn., West Indian *icoca plum*, "*golden plum or cocus plum*," called "*icoca*" in tropical America and "*ouaraye*" on the Senegal, is everywhere cultivated in the Antilles and warmer portions of America. The seed contains 20 to 25 per cent. of fine table oil, called *icoca oil*.

2. *Chrysobalanus ellipticus*, Smeathn.

3. *Chrysobalanus luteus*, Smeathn., both indigenous to Sierra Leone.

Cassuvieæ (Terebinthinæ).

1. *Cashew apple oil (Acajouöl,* G.; *huile de noix de caju,* or *huile d' acajou,* F.), from the seed of *Anacardium occidentale,* Linn., a tree indigenous to South America and the West Indies. At the apex of the edible peduncle, which is about the size and shape of a hen's egg, grows a large, flattened, kidney-shaped nut having a hard shell. Between this and the shell of the kernel is a black, caustic oil which causes inflammation and blisters upon the hand. After removing the hard shell and gummy juice there remains a white edible kernel which contains from 40 to 50 per cent. of pale-yellow oil of a sweetish flavor resembling that of almond oil. Its specific gravity is 0.916 at 59° F., and it is used in Brazil as a table oil.

2. *Semecarpus anacardium,* L., a tree indigenous to the East Indies. The nut, known as the East Indian cashew nut, is about 1 inch long, nearly heart-shaped, flattish, glossy and black. The black caustic oil beneath the hard outer shell is used in the East Indies, like the black caustic oil of *anacardinm occidentale,* as an indelible ink and for writing upon tissues. The ethereal extract of this juice contains the vesicating principle "*cardol,* $C_{21} H_{30} O_2$."

The kernel of this nut is also edible, but contains a thicker oil of inferior quality, having a specific gravity of 0.930.

3. *Pistacia vera,* Linn. The kernels of the pistachio nut yield a greenish aromatic oil known as *pistachio nut oil.* It has a mild flavor and is used as a table oil, but is of no commercial importance, it readily becoming rancid.

4. *Pistacia lentiscus,* Linn., the mastic tree, indigenous to Italy and Greece. By comminuting and boiling the berries, a dark-green, semi-fluid fat, known as *lentiscus oil,* is obtained. By partially solidifying this fat and pouring off the fluid portion, it is resolved into a white crystalline fat melting at 93.2° to 95° F., and a dark green oil which remains fluid even at 46.4°F.

5. *Pistacia cabulica,* Stocks, indigenous to Afghanistan,

where it is known as "*Kussoor*" and to Belloochistan where it is called "*Pista.*"

6. *Mangifera indica*, Linn., the Indian mango tree, yields the finest fruit of the East Indies and Brazil. The oil of the seed is used, but has not yet been described.

Celastrineæ (*Tricoccæ*).

1. *Spindle-tree oil* (*oleum evonymi; Spindelbaumöl*, G.; *huile de fusain*, F.).—The cotyledons of the spindle tree, *evonymus europæus*, Linn., a shrub indigenous to central Europe, contains 28 to 29 per cent. of oil. It is thickly fluid, has a reddish-brown color, a disagreeable odor, and a bitter, pungent taste. Its specific gravity is 0.938, it being the heaviest oil next to castor oil and croton oil. It solidifies at 5° F., separating a reddish coloring matter, which, by careful melting of the fat, remains behind in granules. The oil contains a bitter resin, "evonymin," and yields to water a bitter principle but no free acid. It dissolves with difficulty in spirit of wine, the solution showing an acid reaction.

By saponifying the fat with soda lye, sodium oleate, palmitate, stearate, benzoate and acetate are formed, the latter two remaining in the sub-lye.

Benzoic acid C_7H_5OOH is contained in a free state in the oil, and may be extracted with alcohol; acetic acid exists in the oil as a glyceride = triacetin $\left.\begin{matrix} C_3H_5'''' \\ (C_2H_3O)_3 \end{matrix}\right\} O_3$.

In Southern Germany, Tyrol, etc., spindle-tree oil is used as an illuminant. It is also employed against vermin in the hair of men and animals, and as a remedy for wounds. The capsules are used for dyeing yellow.

2. *Staff-tree oil* (*Celasteröl*, G.; *huile de celastre*, F.), is obtained from the seed of the staff tree, *Celastrus paniculatus*, a common shrub of India. It has a dark red color, and is burned in lamps and at religious ceremonies.

Euphorbiaceæ (*Tricoccæ*).

1. *Croton oil* (*oleum tiglii or oleum crotonis*, *Crotonöl or Grana-*

natillöl, G.; *huile de croton or huile de tilly*, F.). The fixed oil expressed from the seeds of *Croton tiglium*, Linn., = *Tiglium officinale*, Klotzsch. This species of croton is common in a wild state, as well as cultivated throughout Hindostan and some of the East Indian and Philippine Islands, and has been introduced into Japan and other countries. It is about 15 to 20 feet high. The fruit is a tricoccous capsule nearly ¾ inch long, each cell containing a single seed. The seed as found in commerce is about ½ inch long, oblong, flattened upon the ventral surface and marked longitudinally by the slightly elevated raphe. Externally the seed is of a gray-brown color more or less mottled, or of a nearly uniform blackish color where the outer coat has been removed. The testa is thin and brittle, and amounts to about ⅓ of the weight of the seed. It is covered with a white membrane and envelops a solid white kernel rich in oil, which encloses between the two albumen-lamellae, the thin foliaceous embryo. The seed has an oily, afterward very acrid taste; when heated it diffuses a vapor which has a very irritating effect upon the eyes.

Besides albuminous substances and crystals of calcium oxalate, the seed contains in the parenchymatous cells from 30 to 35 per cent. of oil, very seldom 40 to 45 per cent.

Oil	33.25 p. c.	
Organic substances	56.95 "	
albumen therein		18.20 p. c.
Ash	4.00	
Water	5.80	
	100.00	

By pressure the seed yields about 25 per cent. of oil, and by warm pressure about 30 per cent.; more oil is obtained by extraction with ether or carbon disulphide, but the products are not alike, and for officinal internal use the pressed oil only can be employed. The oil is of an orange-yellow to brown-yellow color, quite viscous, and has a peculiar, slightly rancid odor and acrid flavor. It is insoluble in water, but soluble in 36 parts of highly rectified spirits of wine, and readily so in ether and carbon disulphide. It is one of the most powerful cathartics known, and acts when merely rubbed upon the abdomen, producing even bloody stools. When brought in contact with the skin, it causes in a few minutes a burning pain, and later on pustules.

The specific gravity of fresh croton oil is 0.942 at 59°F. and of old oil, 0.955. It solidifies at 3.2° F., and, according to Hanbury, turns the plane of polarization to the left.

Croton oil is a mixture of the glycerides of stearic, palmitic, myristic, and lauric acids, further of œnanthylic acid or pyroterebic acid, caproic, valerianic, butyric, and acetic acids. Oleic acid is not present, but Schlieper found crotonic acid, C_4H_5OOH, which is homologous to oleic acid, and angelic acid, C_5H_7OOH, but, according to Guenther and Frœhlich, no crotonic acid is present, but higher members of the series of oleic acids and tiglic acid $C_5H_8O_2$, which is isomeric, but not identical, with angelic acid.

According to Schlippe, croton oil also contains 4 per cent. of a viscous substance—*crotonol* $C_4H_4O_2$, to which is attributed the vesicating effect of the oil; however, this substance has not been obtained by other chemists.

According to the more recent researches of Senier and John Meck the vesicating principle has to be sought for in the fatty acids with the lowest fusing point and not readily saponifiable, which, however, are first liberated on decomposing the soap with acid. These fatty acids are chiefly contained in the portion of the oil insoluble in alcohol, when for solution at least 7 parts of alcohol are taken for 6 parts of croton oil. Equal or smaller volumes of oil mix with the alcohol.

Nitric acid, either by itself or in connection with nitrous acid, has no effect upon croton oil. By treating a mixture of oil and acid with granulated copper, the oil becomes only more thickly fluid and of a somewhat lighter color. Admixtures of castor oil and other non-drying oils are recognized by solidification.

Concentrated sulphuric acid dissolves readily in croton oil.

The solution added to croton oil colors it somewhat darker, but remains for a short time a clear fluid which, when shaken with water, separates into a turbid yellow-red fluid and into a red fatty substance. By the sulphuric acid reaction foreign admixtures of drying and non-drying oils can be readily recognized, since they immediately make the mixture considerably darker, more turbid and opaque than is the case with pure croton oil.

Potash lye readily saponifies croton oil, the product being a yellow soap.

Only East Indian and English croton oils were formerly known in commerce; the first was yellowish, and the latter, chiefly expressed in London, brown-yellow and more powerful. It was shipped in beer bottles holding about 1¼ lb. net, this mode of packing being still the only one used in England.

For many years croton seed brought by way of Madras, Calcutta, etc., to London, has been bought for the manufacture of croton oil in Germany, and expressed on a large scale by Dr. F. Witte, of Rostock, and Gehe & Co., of Dresden. German croton oil at present supplies not only Germany, Russia and Denmark, but to a great extent America also.

2. *Croton pavana*, Hamilt., indigenous to Assam and Birma, yields the "*Molucca grains*," which furnish an oil similar to croton oil.

3. *Croton oblongifolius*, Roxb., occurs in Bengal under the name of "Baragech," and is used like the preceding varieties.

4. *Croton polyandrus*, Roxb., called "*Duntee*" in Bengal, yields seed which is expressed for oil.

5. *Castor oil* (*oleum ricini—oleum Palmae Christi; Ricinusöl*, G,; *huile de ricin*, F.) is contained in the seed of *Ricinus communis*, Linn., the castor oil plant, indigenous to Southern Asia, but early introduced into all tropical and sub-tropical countries, in many of which it has become naturalized, attaining in the tropics the size of a tree 30 to 40 feet high. It is often cultivated in temperate countries for ornament and other purposes, remaining an annual, varying in size from 4 to 14 feet. The fruit is a subglobular grooved tricoccous capsule which is some-

times smooth, but mostly spinescent. Each cell encloses a single oval or elliptic seed, which is from ⅓ to ⅔ inch long, ⅙ to ⅓ inch broad, flattened on one side, smooth, shining, of a gray color, variegated with yellowish, brown or reddish spots and lines, and with a slightly-raised raphe along the flattish side, and a prominent caruncle near one end. The testa is hard, brittle, fragile; the inner seed-coat is thin, white, and has a brownish chalaza; the embryo is straight, white; has broad foliaceous heart-shaped cotyledons, and is imbedded in an oily albumen, having a bland and scarcely acrid taste.

In India two varieties of castor oil beans are cultivated:

1. *Ricinus communis, minor*, Linn., small seeded variety, with seed 0.47 inch and less long; this variety is expressed for medicinal use.

2. *Ricinus communis, major*, Linn., large-seeded variety, with seed 0.70 to 0.78 inch long; the oil expressed from this seed is used only for technical purposes, as illuminating oil, and for soap boiling.

The seed is odorless, has a sweetish, afterward acrid taste; the parenchymatous cells carry drops of fat and large gluten bodies partially enclosing crystalloids.

The shell amounts to about 20 to 24 per cent. of the entire seed, and contains about 10 per cent. ash. The shelled seed contains seldom less than 50 to 60 per cent. of oil, the other substances being distributed as follows:

	Italian seed.		Indian seed.	
Oil	52.62 p. c.		55.23 p. c.	
Organic substances	36.45 "		34.11 "	
albumen therein		20.50 p. c.		19.26 p. c.
sugar		2.12 "		2.25 "
Ash	2.93 "		3.40 "	
Water	8.00 "		7.26 "	
	100.00 "		100.00 "	

Amongst the organic substances are also found gum-like bodies, starch, resin, bitter principle, a peculiar acrid substance, and, according to Tuson, an alkaloid "ricinin," which is soluble in water and alcohol, but scarcely soluble in ether and benzol.

The former differences in the color, etc., of castor oil were due to the various methods of preparation; thus it was formerly prepared in the East Indies by boiling the pulped seed with water and taking off the oil collected on the surface. This method is still in use for the preparation of illuminating oil from the large-seeded variety, the seed being first roasted over an open fire. The oil is highly colored and very empyreumatic. Formerly the oil was partially pressed hot, as is still done in Greece, and partially cold, the latter process being first commenced in England and yielded "cold drawn castor oil." In Italy, Calcutta and Madras, for the best quality of oil, the seed is freed from the shell by pounding with wooden mallets and the wormy portions carefully picked out, which causes a waste of 30 per cent.

Fig. 215 exhibits a machine for freeing castor seed from its shell, constructed by Rose, Downs & Thompson, and intended for steam power. The seed is brought into the hopper *A* and passes through between two rolls moving at a fixed distance from each other, so that by a gentle pressure the shell is detached from the kernel. The shelled seed in falling down meets a current of air produced in the cylinder *D*, whereby the shells are separated from the seed, which collects by itself in *E*.

For hand-power the machine, Fig. 214, p. 410, may be used, it being constructed according to the same principle.

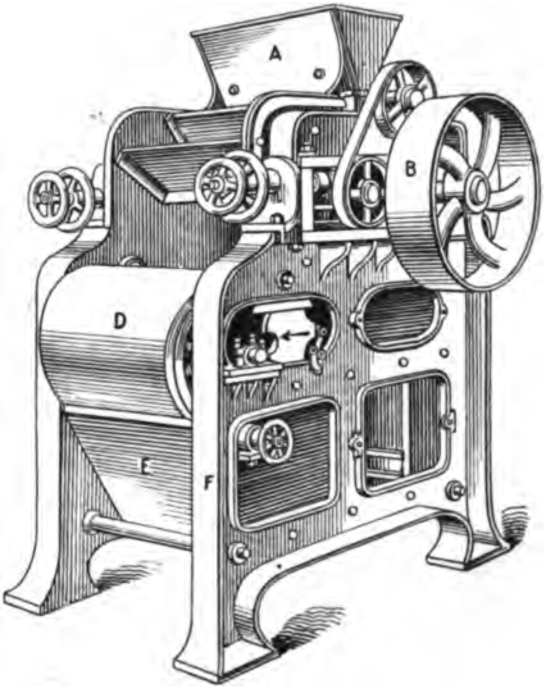
The cleansed seed is comminuted in the usual manner and pressed twice cold, and the third time assisted by heat.

The three pressures yield 46 to 50 per cent. of oil, 220 pounds of cleansed seed giving the following quantities:

1st pressure	57.0 to 64 .	pounds.
2d pressure	28.5 to 31.0	"
3d pressure—illuminating oil	12.5 to 12.5	"

The oil as it escapes from the press is received in well-tinned vessels and allowed to settle, care being had not to expose it to

FIG. 215.



MACHINE FOR SHELLING CASTOR-BEANS.

the sun, which would make it rancid. It is also frequently mixed with some water, and heated to the boiling point to coagulate the albumen and scum. This is carefully removed, and the oil, as soon as cold, is filtered through canton flannel and put into canisters. It is termed "cold drawn," and is the only one fit for medicinal use.

A commoner kind of oil is prepared by the action of hot steam upon the seed and subsequent hot pressure, mixing the obtained oil with animal charcoal and filtering through flannel. In the East Indies the method is sometimes adopted of putting the crushed seed in bags, to boil these in water, and to skim off the floating oil.

In the United States a somewhat different method of extraction is used. The cleansed seed is brought into iron tanks and gently heated, care being had to prevent roasting, since the only object of this operation is to make the oil more fluid. The pressing itself is accomplished by means of hydraulic presses, each provided with a number of movable plates and a cylinder. The oil first expressed runs into a large reservoir. The pressed seed is thrown together in a pile and remains there for one day, when it is again heated in an iron tank and pressed. This gives a second quality of oil which is used as a lubricant. Part of the press-cake is used as fuel, and the other part, in connection with other materials, is employed in the manufacture of fertilizers. By heating with water, as described above under cold drawn oil, the oil obtained by the first pressure is further purified.

In California, where the castor-oil plant has been cultivated for many years, the oil is, however, obtained by cold extraction. The spikes containing the beans should be collected before becoming too ripe, and spread upon a smooth plat of ground to permit the sun to dry and crack them open, when they eject the beans with considerable force. They are then gathered and cleaned by means of a common fanning machine. They should be converted into oil as soon as possible after gathering, as in a few weeks they become rancid, yielding an oil with irritating properties. The beans are first finely ground and subjected to strong pressure by means of a circular screw-press, which is usually from 6 to 8 feet high by 2 or 3 feet in diameter, with open slats through which the oil is forced as the mass is compressed. The oil, as thus extracted, presents a thick, white, milky appearance, and is ready for clarification. This process varies with different manufacturers. At the San Francisco oil works it is rendered clear by steam heat, which causes the deposition of the extraneous matter, but in Marysville and Los Angeles it is clarified by means of solar heat. Tanks of tin of convenient size are provided, screened in some instances with glass covers to prevent the settling of dust on the surface of the oil. These tanks are filled with the milky product of the press and exposed to the rays of the sun, which settles the foreign matter, leaving about six inches of clear oil on the top during the course of the day, which at nightfall is carefully drawn off by means of stop-cocks in the sides of the tanks. These are again filled with the oil and the process repeated every day. The oil clarified by steam heat is straw-colored, of a slight greenish hue. That obtained by solar heat is lighter colored, almost transparent, and of superior clearness.

California oils are perfectly soluble in alcohol, miscible with the fixed and essential oils, free from acidity or acridity. Their specific gravity is between 0.940 and 0.960, which is fully equal to the imported oils.

Castor oil is thickish, 203 times heavier than water at 59° F., and 377 times heavier at 45.5° F. It is very viscid, colorless, or of a slightly greenish-yellow color, and transparent. It has a mild flavor with a pungent after-taste, the latter being very slight in Italian and French oil, but more pronounced in American oil. In medicine it is used as a mild purgative. Exposed to the air it becomes rancid, and in that case should not be used internally, as it acquires injurious and even poisonous qualities. By long exposure to the air it becomes thick and forms a viscid mass, which, however, does not become solid. Spread out in a very thin layer it acquires some solidity, but this is rather due to its partly soaking into the base and partly to the action of dust upon the oil.

The specific gravity of castor oil is

At 53.5° F.	0.9699
" 59° "	0.9667
" 77° "	0.9575
" 201.0° "	0.9081

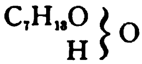
Castor oil is, according to Bouis and Silbermann, without rotating power, while, according to Hanbury, it turns the plane of polarization to the right. It becomes turbid at 10.5° F., and solidifies at 1.5° to —0.5° F. The American oil, being richer in stearin, solidifies at 14° to 10.5° F.

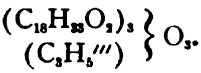
Castor oil is miscible in all proportions with absolute alcohol and glacial acetic acid. It is soluble in 4 parts of alcohol of 0.835 or 0.850 specific gravity at 59° F., and mixes without becoming turbid with equal parts of the same solvent at 77° F. In petroleum-ether it is entirely insoluble. It is readily saponified to a white transparent soap—4 parts oil to 1 part caustic alkali—which dissolves in pure water without making it turbid or opalescent. On stirring, the soap solution foams strongly.

Castor oil contains, according to Ure:—

Carbon	74.00	per cent.
Hydrogen	10.26	"
Oxygen	15.71	"

Of the acids occurring in castor oil, ricinoleic acid $C_{18}H_{34}O_3$ is the most prevalent, stearic and palmitic acids being present only in small quantities.

The oil boils at 527° F., oenanthol $C_7H_{14}O$, oenalthylic acid  $\left.\begin{array}{r}C_7H_{13}O\\H\end{array}\right\}O$, and acrolein C_3H_4O, passing over. When about one-third of the oil is volatilized in the form of these products, the residue after removal from the fire, suddenly swells up and solidifies to a viscid, spongy mass, which is insoluble in water, alcohol, and ether, and on boiling with potash lye gives a clear soap paste.

Nitric acid of 1.18 specific gravity, shaken with castor oil, produces no effect; the mixture is whitish but turns yellow after several hours. On shaking with acid of 1.30 specific gravity, which contains nitrous acid, the oil immediately turns yellow and becomes thick in two hours. By adding to the last mixture starch or granulated copper, the oil is changed in 6 to 7 hours into a solid white mass, *ricinelaïdin*  $\left.\begin{array}{c}(C_{18}H_{33}O_2)_3\\(C_3H_5''')\end{array}\right\}O_3$.

Concentrated sulphuric acid first produces a yellow coloring, which gradually becomes darker yellow, and, on stirring, passes into a reddish hue.

A solution of 30.75 grains of *nitrate of silver* in 0.35 ounces of water, mixed with 3.0 ounces of absolute alcohol, is not reduced by boiling with castor oil.

Of *iodine* up to 52 per cent. is dissolved by castor oil.

Potash lye shaken with castor oils gives a white granulated mass.

In testing for adulterations, consistency, color, odor, and taste should first be considered. On treating, as above, with nitric acid and starch, pure castor oil solidifies to a whitish mass in 6 to 7 hours. In the presence of foreign oils solidification is not complete; the mass is yellowish or reddish and remains smeary.

Finkener recommends the alcohol test for testing castor oil, the latter dissolving in nearly every proportion in alcohol of 0.829 specific gravity at 63.5° F., while oil adulterated with not more than 10 per cent. of other fat oils gives very turbid solutions, from which it later on settles on the bottom of the glass. For making the test, 1 volume of oil and 5 volumes of alcohol are used.

Saponification number of the oil	201–203
Iodine number of the oil	93–94
" " of the fatty acids	87–88
Fusing point of the fatty acids	55.4° F.
Solidifying point of the fatty acids	37.4° F.

Although much castor oil is used for medicinal purposes, in the manufacture of pomades, etc., the amount is small as compared with the enormous quantities used in the manufacture of soap, as illuminating oil, (in China fresh castor oil is said to be used even as table oil), for the preparation of so-called leather-oil, and for other technical purposes.

Turkey red oil is a preparation used in dyeing and calico printing, especially in the production of "Turkey red," whence the name applied to this product, and is manufactured from olive, cotton-seed and similar oils. A superior article is obtained by mixing castor oil with concentrated sulphuric acid, carefully avoiding, by cooling and slowly adding the acid, the heating of the mass above 95° F. and the evolution of larger quantities of sulphurous acid. Water is then added, and, after allowing to settle, the lower layer is drawn off and washed with common salt solution until the wash water shows but a slightly acid reaction. Enough ammonia is then run in and carefully mixed with the washed oil until a sample forms a perfect emulsion with water.

The acid Turkey red oil not neutralized with ammonia may be resolved into two portions, one soluble and the other not soluble in water. The operation is as follows:

The product of the reaction obtained by mixing oil and sulphuric acid is dissolved in ether, freed from sulphuric acid by shaking with common salt solution, and then repeatedly agitated with water. The combined aqueous extracts are mixed with common salt, whereby the *water-soluble portion* is separated as oil. The ethereal layer on evaporating leaves behind the *portion not soluble in water.*

The investigations of Benedikt and Ulzer* have shown that the soluble portion of Turkey red oil consists of *ricinoleosulphuric acid*, which is formed according to the following equation:

$$\underset{\text{Ricinoleic acid.}}{C_{18}H_{33}O_2.OH} + H_2SO_4 = \underset{\text{Ricinoleosulphuric acid.}}{C_{18}H_{33}O_2.OSO_3H} + H_2O.$$

Ricinoleosulphuric acid is miscible in all proportions with water, its watery solutions foaming like soap solutions. From the aqueous solutions the ricinoleosulphuric acid may be separated by common salt, moderately dilute sulphuric acid and hydrochloric acid, the acid collecting on the bottom of the vessel as a heavy oil. By then shaking with ether three layers are obtained; and as the acid is soluble with difficulty in this solvent, it separates as the middle layer, containing much ether. With lead, copper, calcium and barium salts it gives smeary precipitates.

Ricinoleosulphuric acid is not decomposed by boiling its aqueous or alkaline solutions, but by boiling it with dilute hydrochloric or sulphuric acid it readily splits into ricinoleic and sulphuric acids.

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* Zeitschrift f. d. chem. Industrie, 1887, 298.

Kobert has pointed out that Turkey red oil possesses poisonous properties.

The *insoluble portion* of Turkey red oil consists largely of free ricinoleic acid, and generally contains some neutral fat and perhaps anhydrites of ricinoleic acid.

For the preparation of Turkey red oil, castor oil cannot be replaced by another oil or by oleic acid, the other fatty acids, when treated with sulphuric acid, yielding saturated oxyacids and their sulphuric acid esters, for instance:

$$C_{18}H_{34}O_2 + H_2SO_4 = C_{18}H_{35}(OSO_3H)O_2.$$

Oleic acid. Oxystearosulphuric acid.

By the excess of sulphuric acid the oxystearosulphuric acid is mostly decomposed:

$$C_{18}H_{35}(OSO_3H)O_2 + H_2O = C_{18}H_{35}(OH)O_2 + H_2SO_4.$$

Oxystearosulphuric acid. Oxystearic acid.

Hence, castor Turkey red oil contains exclusively non-saturated acids, and oleic acid and olive Turkey red oils saturated acids. This explains the reason why the former possesses great oxidizing power, which is the chief point in dyeing, while the latter lack this property.

Commercial Turkey red oils ase more or less thickly-fluid, transparent and yellow in thin layers, brown in thicker layers.

A sample of Turkey red oil should yield with water an emulsion separating drops of oil only after standing for some time. Stir together in a graduated test-tube 1 part of the oil to be tested, first with a small quantity, and then successively, with 10 parts by volume of warm water; make the same test with a standard commercial product and compare the behavior of the two emulsions. Both fluids must show the same slightly acid reaction with litmus paper, but should not be neutral or exhibit an alkaline reaction. Should the latter be the case, add acetic acid drop by drop until the reaction and degree of turbidity of both fluids are alike.

Good qualities of oil dissolve perfectly clear in ammonia, no turbidity being formed by the subsequent addition of much water.

An alcoholic solution of Turkey red oil not prepared from castor oil is the more turbid the more unchanged oil (neutral fat) is present.

For a dyeing test two pieces of cotton cloth of the same size are prepared with the samples of Turkey red oils to be compared. For this purpose mix 1 part of the oil with 10 to 20 parts water—many adding ammonia until the fluid is just clear—saturate the pieces of cloth with the mixture, and dry. Then mordant slightly with alumina, dye with alizarin, or print with steam rose-color, and finish the colors in the known manner by soaps, brightening, etc.

The value of a Turkey red oil depends mainly on its total content of fat, whereby is to be understood the sum of the portion of the acidulated oil insoluble in water (fatty acids, oxy-fatty acids and neutral fat), and of the oxy-fatty acids obtainable by decomposition of the soluble sulphurized acids. For more exact examinations the contents of neutral fat, sulphurized fatty acids, ammonia, etc., are determined. Finally, to draw a conclusion regarding the nature of the fat used in the preparation of the Turkey red oil, the total fat is titrated according to Hübl and the number determined.

As an example of the composition of Turkey red oil, the analysis of a product of acknowledged good quality may be given:

Portion of the fat mass soluble in water	9.5	per cent.
Insoluble portion of the fat mass neutral fat	1.3	"
Insoluble portion of the fat mass fatty acids	47.2	"
Total fat	58.0	"
Ammonia	1.8	"
Total sulphuric acid	4.6	"

Castor oil comes into commerce from the East Indies—Calcutta, Madras, Bombay—and Italy, and a comparatively small portion also from America.

The Italian oil is considered the best as regards color and taste, and consequently brings a much higher price than the East Indian product. Much East Indian seed is also expressed in Italy.

London is, so to say, exclusively the European market for East Indian castor oil, while the Italian product is procured directly from the producers, who are scattered throughout the Upper Italian cities, especially Verona, Padua, Vicenza, Trieste, etc.

East Indian and Italian castor oil comes into commerce in tin canisters generally holding 20 kilogrammes (44 lbs.) net. East Indian oil is also exported in larger canisters, while the finest quality of Italian oil for medicinal purposes is also packed in canisters holding 10 kilogrammes (22 lbs.).

The seed of the following varieties of *Ricinus* is also used in different warm countries for the production of oil, which is mostly employed for illuminating purposes:

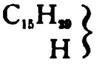
Ricinus viridis, Willd.; *R. ruber*, Rumpf; *R. inermis*, Jacq.; *R. lividus*, Willd.; *R. africanus*, Willd.; *R. americanus*, Aldini.

6. *Purgir-nut oil* (*oleum cicinum*, *Curcasöl*, G.; *huile de pignon d' Inde*, F.) is contained in the seed of *Jatropha curcas*, Linn. = *Curcas purgans*, Ad. a small tree or shrub indigenous to India, and cultivated in Africa and South America. The seed resembles the castor-bean, but is larger; it is black, not glossy, somewhat rough, and marked with numerous small cracks. It is inodorous; the kernel has a sweetish and oily taste, which gradually becomes acrid and burning. The seed is shelled before pressing and contains 30 to 40 per cent. of oil, the average composition being as follows:

Oil	37.50 p. c.	
Organic substances	50.50 "	
albumen therein		16.24 p. c.
Ash	4.80 "	
Water	7.20 "	
	100.00 '	

Besides, albumen, sugar, starch, and casein are found among the organic substances.

The oil is of a lighter color than linseed oil, inodorous, has a mild flavor with a pungent after-taste, produces no inflammation upon the skin, and is a strong purgative. It is much more limpid than castor oil, and has a specific gravity of 0.915 at 59° F. At 17.5° F. it becomes a butter-like mass, and solidifies at 10.5° F. It is sparingly soluble in water, but entirely so in 24 parts of alcohol.

It contains ricinoleic acid, because when distilled with potash lye, it yields capryl alcohol $C_8H_{18}O$, and, further, stearic, palmitic, and myristic acids. The isocetic acid  $\left.\begin{matrix}C_{15}H_{29}\\H\end{matrix}\right\}O$, found by Bouis melts at 131° F.; it is a mixture of of 70 parts palmitic and 30 parts myristic acid.

The oil is much used for illuminating purposes, burning without smell or smoke, and in the manufacture of soap. The oil pressed from African seed is used as a lubricant in England.

Although the oil does not possess completely drying properties, it undergoes a change in the heat, and boiled with ferric oxide, the mixture is used as a varnish.

7. *Jatropha glandulifera*, Roxb. The oil obtained from the seed of this plant has a straw color, about the consistency of castor oil, and a specific gravity of 0.963 at 59° F. It contains considerably more stearic and palmitic acid, it solidifying at 23° F. It is used externally as an irritant.

8. *Jatropha multifida*, Linn., has edible leaves known as "Nicaragua cabbage." The root is used as a purgative and the seed contains an oil known as *pinhoï oil* which is very similar to, if not identical with, purgir-nut oil.

9. *Euphorbia Lathyris*, *Linn.*, the caper spurge or garden spurge, a South European herb, cultivated in gardens and somewhat naturalized in North America. The seed was formerly officinal as *semen cataputiæ minoris;* it is about ⅛ inch long, brown marbled with gray, and rugose. The cotyledons

contain 35 to 40 per cent. of oil known as *spurge oil or purging oil* (*Purgirkernöl*, G.; huile d' epurge, F.). The oil has a mild, afterward acrid, taste, is of a pale yellow color, and of specific gravity 0.926 at 59° F. It is used as lamp oil and in the manufacture of soap. It solidifies at 12° F.

10. *Hura crepitans*, Linn., sand box-tree, a tree indigenous to tropical America. The seed contains a clear oil, slightly colored, known as *sand box-tree oil*, with purgative properties.

11. *Andi Gomessi*, Juss. The seed of the fruit "coco de purga" yields an oil which is used medicinally in Brazil. It is pale yellow, without odor or taste, and has a specific gravity of 0.927. It is intermediate between drying and non-drying oils.

12. *Siphonia elastica*, Linn. The oil obtained from the seed of this tree is known as *caoutchouc tree oil*, and is well adapted for the manufacture of a hard soap and printing ink.

Of other Euphorbiaceæ which yield oil belong

1. *To the drying oils* (which see): *Euphorbia dracunculoides*, Lam.; *Elaeococca verrucosa*, Comm.: *Aleurites triloba*, Linn.; *A. gabonensis*, Linn.; *A. cordata*, Linn.; *Baliospermum montanum*, Müll.; *Buchanania latifolia*, Willd.; *Bottleria tinctoria*, Roxb.

2. *To the solid fats* (which see): *Stillingia sebifera*, Juss.

Sapindaceæ.

Ungnadia oil. From the fruit of *Ungnadia speciosa*, Endl., a small tree or shrub indigenous to Texas and naturalized in Mexico and a portion of western North America, an oil is obtained which, as regards taste, resembles almond oil. The fruit is a broad trilobate, tricoccous, leathery, smooth capsule, each cell enclosing a single nearly round seed. The testa is dark chestnut brown, fragile, very smooth and lustrous, and provided inside with a thin membrane. The seed is without albumen, it being filled up by the embryo. The cotyledons are very thick and fleshy and almost semi-spherical. The seed has an agreeable sweet taste not unlike that of walnuts and almonds, and produces nausea and even vomiting. It contains 46 to 50 per cent. oil; when ignited the seed burns like walnuts or Para nuts with a luminous, sooty flame.

The oil expressed from the seed, or extracted with ether or benzine, has a mild, agreeable, almond-like taste, and is very suitable as a table oil, it lacking the disagreeable properties of the seed.

The oil is pale-yellow and limpid; its specific gravity at 59° F. is 0.9120, at 212° F., 0.854, and it solidifies to a white mass at 10.4° F. It keeps for a long time in the air without becoming rancid, it sharing this property with ben oil. It contains no free fatty acids.

The oil consists chiefly of the glyceride of oleic acid besides small quantities of the glycerides of palmitic and stearic acids; 22 per cent. palmitin and stearin and 75 per cent. olein.

Saponification number of the oil	191 to 192
Iodine number of the oil	81.5–82
Iodine number of the fatty acids	86–87
Content of insoluble fatty acids (Hehner's number)	94.12 p. c.
Fusing point of the fatty acids	66.2° F.
Solidifying point of the fatty acids	50° F.

Hippocastaneæ (*Malpighinæ*).

Horse-chestnut oil (*Rosskastanienöl*, G.; *huile d' hippocastane*, F.) from the fruit of the horse-chestnut, *Aesculus hippocastanum*, Linn., a tree indigenous to Persia and India, naturalized in Europe and America. Horse-chestnuts contain, besides starch, sugar, gum, and bitter principle, 6 to 8 per cent. of oil, which is obtained in a peculiar manner. The chestnuts, comminuted together with the shell, are boiled in water containing sulphuric acid, and the oil which collects on top of the concentrated starch syrup formed, is skimmed off. The fresh oil has a brownish-green color and a peculiar flavor, with a bitter after-taste. It keeps well, has a specific gravity of 0.929 at 59° F., and solidifies at 34.25° F. Its principal use is as an external remedy for gout, rheumatism, and neuralgia. It is readily saponified.

Malvaceæ (*Columniferæ*).

1. *Cottonseed oil* (*Oleum gossypii—Baumwollensamenöl*, G.; *huile de cotton*, F.) is obtained from the seed of the different varieties of *Gossypium*, Linn., of which there are more than twenty, though, according to Hamilton, there are but three distinct species—

1. *Gossypium album*, with white cotton and white seeds.
2. *Gossypium nigrum*, with white cotton and black seeds.
3. *Gossypium croceum*, with yellow cotton, all the rest being but varieties of them.

The most important varieties, however, are *Gossypium herbaceum*, indigenous to Central and South Asia, and largely cultivated, especially in North America and Southern Europe; *G. arboreum*, L., cultivated in the East Indies; *G. barbadense*, L., in the West Indies; *G. religiosum*, L., in the East Indies, especially Bengal, and in China where it is principally cultivated.

The seed is small in size, and varies in shape from ellipsoid to fusiform, and in color from pale gray through yellow and brown to almost black. Like its relatives, rape seed, linseed, and sesamé seed, it is rich in oil, albuminoids, and digestible cellulose. Its composition varies even more than its qualities. Of forty samples examined by the "American Analyst," the amount of oil varies between 10 per cent., with an immature and badly dried Sea Island seed, to 29 per cent., with a fully matured Egyptian seed. The albuminoids and other nitrogenous substances varied from 18 to 25 per cent., and the lignin or woody tissue from 15 to 25 per cent.

These variations depend partly upon the variety or species of the cotton, upon the climate, season, and soil where it is grown, upon the care and skill bestowed upon its culture, and upon the mode employed in its separation, cleaning, and treatment. A fair idea of the composition of cotton seed, and these variations, is given by four analyses by the "American Analyst" of American samples of about the same appearance and grown in the same latitude:

Constituents.	South Carolina.	Georgia. 1.	Georgia. 2.	Georgia. 3.
Water	9.5	10.1	9.8	8.2
Cotton-seed oil	20.1	16.2	17.1	19.6
Nitrogenous compounds, including albuminoids	17.8	17.4	17.2	18.1
Ammonia-making compounds	2.3	2.9	3.2	3.7
Gum, sugar, and soluble starch	.8	.9	.7	.9
Cellulose, starch, and resin	26.2	27.4	26.1	20.7
Ligneous tissue (lignin)	17.6	19.2	19.8	22.4
Ash { phosphate of lime, silica, alumina, iron, magnesia, potash, soda, etc. }	5.7	5.9	6.1	6.4
	100.0	100.0	100.0	100.0

Peeled Egyptian seed showed the following composition:

Oil	23.95 per cent.	
Organic substance	59.91 "	
Albumin therein		27.20 per cent.
Ash	8.60 "	
Soluble phosphates therein		1.10 "
Water	7.54 "	
	100.00 "	

The oil consists of:

Carbon	76.40 per cent.
Hydrogen	11.40 "
Oxygen	12.20 "
	100.00 "

One hundred pounds of seed give on an average:

Hulls with lint	49 to 46 pounds.
Cakes	37 to 38 "
Oil	14 to 16 "
	100 to 100 "

The hulls are used either as fuel or fed together with the press-cakes; recently they have been recommended for the manufacture of paper, the product, it is claimed, being of a good quality.

The manufacture of oil from the seed is not a new enterprise, though it is only within a comparatively short time that it has grown to such large proportions that, according to an able statistician, the factories throughout the world engaged at the present time in its production exceed a thousand; the capital invested, ten millions of dollars; the operatives directly employed, thirty thousand, and the amount of its annual output a half million tons.

From a paper read before the Southern Underwriters' Association, at Atlanta, Georgia, by Mr. Henry V. Ogden, of New Orleans, La., we make the following extracts in regard to early American attempts to manufacture the oil:

"The first attempt was made at Natchez, Miss., in 1834. So far as can be ascertained, the honor of the first attempt belongs to Messrs. James Hamilton Couper and Samuel Plumber, of Georgia, and associated with them were Mr. Follet, of Norfolk, Va., and Major Anderson Miller, of Louisville, Ky. The late Archibald Dunbar and other prominent citizens invested liberally of their means and shared the pecuniary loss that followed. In every respect, so far as known, the attempt was a disastrous failure.

"In the year 1852, just eighteen years later, it attracted the attention of William Wilbur and Frederick Goode, of New Orleans. These gentlemen embarked their all in a new attempt to give it practical value, and they conceived and carried out the plan of a mill, machinery, and process of extraction which has been the inspiration of much that followed. Their improvements enabled them to make oil and clarify it; they made the first soap and sold the first oil cake, but they did so only to share the fate of their predecessors of 1834, for, like them, they were pecuniarily ruined. They had, however, succeeded far enough to convince themselves and demonstrate to others the possibility of the industry.

"In the year 1855, Mr. C. W. Bradbury, of New Orleans, engaged in the enterprise. He was the first to demonstrate beyond any question the feasibility of the manufacture; but his operations were interrupted by the breaking out of the civil war. Messrs. Paulin Martin, F. M. Fisk, Paul Aldige, and A. A. Maginnis, of New Orleans, engaged also in the business, and were interrupted in its successful prosecution by the war. In 1855 a mill was established in Cincinnati and successfully operated. Captain Jackson Warner, who was an agent for the purchase of seed for this mill, says that on visiting the farm of Mr. Joseph Davis, of Mississippi, for the purchase of seed, his attention was called to the dwelling of Mr. Davis, which was handsomely painted twenty years ago with paint in which cotton-seed oil was used. Mr. Davis told him that the oil was expressed on his farm by a small wedge-press. It was used at Athens, Ga., for the same process by Dr. Camak."

In 1867, just after the war, there were seven mills in the country; in 1870, twenty-six; and in 1880, as will be seen from the accompanying table taken from the Tenth Census Report, forty-five, six of them in New Orleans, which alone in that year employed 1525 hands, paid out $374,142 in wages, and produced $2,742,000.

STATES AND TERRITORIES.	No. of establishments.	Capital.	Average number of hands employed.			Total amount paid in wages during the year.	Value of materials.	Value of products.
			Males above 16 years.	Females above 15 years.	Children and youths.			
The United States.	45	$3,862,300	3114	33	172	$880,836	$5,091,251	$7,690,921
Alabama	2	82,000	150	......	......	$42,500	$158,000	$247,982
Arkansas	4	275,000	237	......	......	79,400	378,000	590,000
Connecticut	1	2,800	......	......	......	....	500	575
Louisiana	12	1,557,500	1352	19	75	422,165	2,280,910	3,739,466
Mississippi	8	450,000	440	3	66	94,860	371,080	560,363
Missouri	2	80,000	55	......	......	18,750	80,000	140,000
Ohio	1	150,000	45	......	10	7,450	400,000	435,000
Rhode Island.....	1	125,000	32	3	......	14,899	415,820	458,085
Tennessee	9	935,000	644	4	18	163,340	812,000	1,235,000
Texas	4	202,000	151	4	3	36,272	192,441	276,450
Virginia	1	3,000	8	......	......	1,200	2,500	8,000

From a report on the "Cotton-Seed Oil Industry," by Professor E. W. Hilgard, published in Vol. V. of the Tenth Census of the United States, Washington, 1884, we give the following table, showing the seed worked and products marketed by twenty oil mills in different States:

NAMES.	LOCATION.	WORKING CAPACITY.				Hullers.	Presses of boxes.		PRODUCT PER TON.				Cotton seed used in a season.	SOURCE OF SUPPLY.	AVERAGE PRICE.
		Tons of seed used.		Estimated gallons of oil.			Presses.	Boxes.	Kernels.	Hulls.	Oil cake.	Crude oil.			
		daily.	yearly.	daily.	yearly.										
						No.	*No.*	*No.*	*lbs.*	*lbs.*	*lbs.*	*galls.*	*tons.*		
Crescent City Oil Company	New Mechanicham, La.	150	......	5500	......	4	12	240	1000	1000	775	37½	12,726½	Mississippi River valley, Texas and Alabama.	$10.
Maginnis Oil Works	New Orleans, La.	......	3,500	......	115,500	6	13	200	......	......	700	30–35	17,000	Mississippi, La., Texas, Alabama and Florida.	$12–15.
Planters' Oil Company.	" "	......	20,000	......	640,000	6	14	84	various.	various.	various	various.	20,000	Miss. River and tributaries, Alabama and Texas.	various.
Iberia Oil Mill	New Iberia, La.	10	......	320	......	1	2	12	615*	1385	720	32	1,200	Bayou Teche and Opelousas.	$6.
Hamilton Oil Mills	Shreveport, La.	60	......	1920	......	3	3	63	1000	1000	700	32	12,000	Bayou Wincey and Red River, etc.	$9.
Yazoo Oil Works	Yazoo City, Miss.	......	......	1100	......	1	6	32	1000	1000	720	30–35	2,500 †	Yazoo and Tallahatchee rivers.	$7.50 to 8.50 delivered.
Refuge Oil Works	Refuge, Miss	40	......	1240	......	2	4	60	1000	1000	770–785	30–32	7,000	Mississippi River from Vicksburg to Helena.	$9.50 or 7 net to farmers.
Friar's Point Oil Mill	Friar's Point, Miss.	......	......	1260	......	2	3	45	......	......	700–720	34–36	3,500	Vicksburg to Memphis.	$9 to 9.50.
Augusta Oil Company.	Augusta, Ga.	20	......	600	......	1	4	......	1000	1000	730–740	25–35	867	Georgia and S. Carolina.	$9 to 11.50.
Savannah Oil Company	Savannah Ga.	30	......	900	......	1	8	32	......	......	......	......	first season	Georgia, South Carolina, and Florida.	
Galveston Oil Company	Galveston, Tex.	......	......	......	......	5	10	150	......	......	......	......	......	Texas	$6 at R R. sta-[tions.
Calvert Oil Company	Calvert, Tex.	......	......	800	......	2	2	30	500	1500	763⅓	30	2,378	Robertson County	$5.
Bryan Manufacturing Company	Bryan, Tex.	......	5,000	......	162,500	1	4	104	1240	760	850	32½	2,244	Brazos, Burleson, and Robertson counties.	$7.
Brenham Oil Mill (burned).	Brenham, Tex.	......	......	......	......	......	......	......	......	......	......	......	......	......	$4.50 delivered.
Callahan Oil Works	Hempstead, Tex.	40	......	1280	......	......	......	......	900	1100	750	28–35	3,000	Vicinity and stations on Houston&TexarkanaRR.	$6.
Schumacher Oil Mill	Navasota, Tex.	20	......	600	......	1	4	......	1000	1000	750	30	2,000	Neighborhood	$6 to 9.
Cotton-seed Oil Mills	Raleigh, N. C.	‡	......	50	......	......	......	......	1000	1000	1100	22	400	East & Middle N. Carolina	$10.
Southern Oil Works	Memphis, Tenn.	60	......	1820	......	......	......	......	......	......	......	......	10,000	Southern States.	
Panola Oil and Fertilizing Company.	" "	75	......	2400	......	2	6	90	1000	1000	varies	varies	10,000	Neighboring States	$7 to 12.
Hope Oil Company	" "	......	......	......	......	1	8	......	......	......	......	......	......	Tennessee, Mississippi, and Arkansas.	$9.

* The huller does nothing but grind or cut the seed; the shake divides or separates the kernels from the hulls; 1 to 2¼.

† Half season lost.

‡ 300 bushels of seed per day.

This partial statement is supplemented by a summary by Henry V. Ogden, of New Orleans. He says: "Taking my estimate of the consumption of seed by forty oil mills this season (1882), the proportion and value of the total product may be summed up as follows:

410,000 tons of seed, yielding 35 gallons crude oil to the ton, are 14,350,000 gallons, worth 30 cents per gallon ..	$4,305,000
Same amount of seed, yielding 22 pounds cotton lint to the ton, is 9,020,000 pounds cotton, worth 8 cents per pound	721,600
And yielding also 750 pounds of oil cake to the ton (2240 pounds) is 137,277 tons of cake at $20 per ton	2,745,540
	$7,772,140
Deduct the sum paid for the seed, say..................	4,100,000
And there remains for value gained in manipulation of seed	$3,672,140."

From September 1, 1883, to September 1, 1886, there were exported from New York 88,871 barrels, and from New Orleans 186,720 barrels, making a total of 275,591 barrels from the two ports.

According to the Extra Census Bulletin issued in Washington, March 15, 1894, there are in the United States 119 establishments engaged in the manufacture of cotton-seed oil and cake with an output valued at $19,335,947. The chief cotton-seed presses are located at the following points:

Alabama: Selma, Mobile, Montgomery, Eufaula, Huntsville.

Arkansas: Little Rock, Argenta, Fort Smith, Texarkana, Brinkley, Helena.

Georgia: Atlanta, Augusta, Albany, Columbia, Macon, Rome.

Illinois: Cairo.

Louisiana: New Orleans, Shreveport, Baton Rouge, Monroe.

Mississippi: Clarksdale, Columbus, Canton, Grenada, Greenville, Meridian, Natchez, Vicksburg, West Point.

Missouri: Saint Louis.

North Carolina: Charlotte, Raleigh.

Tennessee: Memphis, Jackson, Nashville, Dyersburgh.

Texas: Brenham, Dallas, Galveston, Houston, Palestine, Waco.

When well stored and properly ventilated, cotton-seed keeps sweet for twelve months. If allowed to become damp, or stored too long in bulk, it grows heated and is liable to spontaneous combustion.

Manufacture of cotton-seed oil.—The seed when landed at the mill is first examined. If too damp or wet it is dried by spreading it over a floor with free access of air, exposing it on frames to the sunlight in warm weather, or by kiln-drying. Drying is the exception rather than the rule in the United States. Cotton ginning is so carefully done that the seeds have little or no opportunity to become wet. Besides this, the seed is generally held at the gins for some time before it is sold to the oil manufacturer.

The first process in preparing the dry seed for the mill is to free it from dust. This is effected by shaking it in a screen or in drums lined with a fine metallic net and containing a strong magnet to which any iron nails will adhere, which are frequently present. From the drums the seed drops into a gutter leading to a machine which removes the lint left by the gin. This is done by a gin constructed for the purpose, with saws closer together than the ordinary cotton-gin. An average of twenty-two pounds of short lint is taken from a ton of the seed. This product, called "linters," is used in the manufacture of cotton batting.

For stripping the seed of its fibre by chemical means Wm. L. Dudley* proposes the following process (U. S. Patent, 344,951) devised by him and N. W. Perry:

The seed after linting is subjected to the action of nitrogen trioxide, N_2O_3 and sulphur dioxide, SO_2, either in the above order or mixed together; enough air attending them to "regenerate" the nitrogen dioxide NO. This is probably best accomplished by having the seed descend a chute slowly through which a current of nitrogen trioxide is ascending, and then into a chute where sulphur dioxide and air are ascending; or they may descend through a chute having an ascending current of nitrogen trioxide, sulphur dioxide, and air. After a few seconds' exposure to these gases under proper conditions, the fiber on the seed has changed very little in appearance, but its structure is so completely destroyed that the slightest friction causes it to fall into an impalpable powder. The seed is left perfectly smooth, showing no signs of corrosion. It has a slight acid reaction on the outside, but the acid is speedily removed by washing. The seed-coat is very hard, and is impervious to the gases. No trace of acid has ever been discovered in the interior. The seed germinates very quickly if planted. The acidity may also be removed by blowing lime dust on the seed as soon as it comes from the "cleaner" which removes the disintegrated fiber; or it may be carried by a conveyer through lime water and then through a dryer. The seed is now ready to be crushed and pressed, or it may be shipped and stored as well as Egyptian or "sea-island" seed.

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* Jour. of Analytical and Applied Chem., Vol. VI., No. 3, March, 1892.

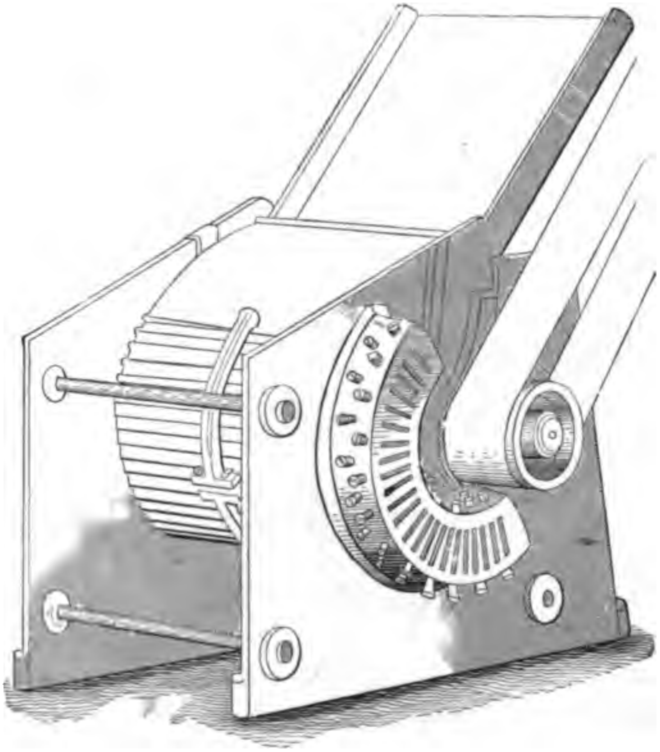
The "cleaner" referred to above may be any good grain cleaner. The disintegrated fiber is quite dry, and is easily converted into glucose.

The nitrogen trioxide and sulphur dioxide may be generated by any of the well known processes, but the ordinary methods employed in sulphuric acid making are the most economical. In fact, this process should be operated, possibly, in connection with such works; the gases escaping from the cotton-seed chute being absorbed in the tower or conveyed into the leaden chamber, so that there is no loss.

The clean seed is transferred to the sheller or huller, which consists of a revolving cylinder containing twenty four cylindrical knives and four back knives. The sheller revolves at great speed, and as the seed is forced between the knives the pericarp or hull is broken and forced from the kernel.

Fig. 216 shows Well's Champion Cotton-seed Huller. It is a substantial machine, and is so constructed that the larger pieces of iron or other foreign substances found in the seed will not enter between the cylinder and concave knives, while smaller pieces, such as nails and the like cannot damage it, care being taken to place the top concave knife close to the cylinder knife. It will hull, perfectly clean, thirty tons of dry seed in ten hours, and will hull damp or green seed fully as well, though not quite so fast. The huller is manufactured by The Stillwell-Bierce & Smith-Vaile Co., of Dayton, Ohio.

FIG. 216.

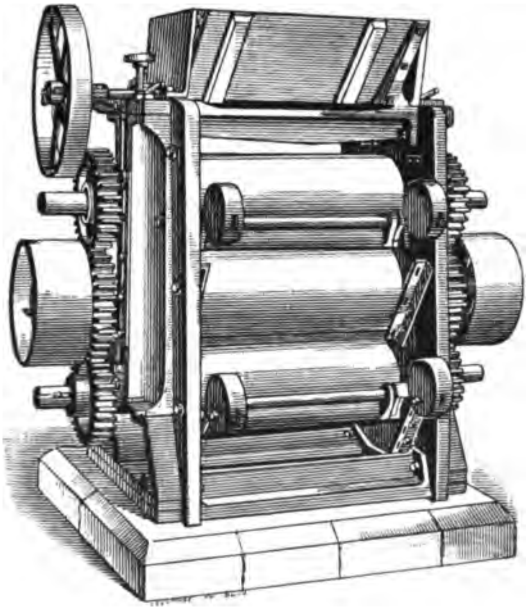


WELL'S CHAMPION COTTON-SEED HULLER.

The mixed shells and kernels are separated in a winnowing machine by a strong blast of air. This removal of the husk makes a vast difference in the meal cake, a desiccated or decorticated cake being five times more nutritious and wholesome than an undecorticated cake.

Being thus cleaned, shelled, and separated, the kernels are carried by a system of elevators to the upper story, and then pass down into the crusher rolls to be ground to flour. The rolls shown in our illustration (Fig. 217) are manufactured by the Stillwell-Bierce & Smith-Vaile Co., of Dayton, Ohio, and have a capacity of 20 to 100 tons of seed per day. They are made 3, 4, or 5 rolls to a stack, and 24, 30, 36, and 42 inches in length, to suit capacity and requirements. The hopper on top contains an adjustable feeding device for regulating and evenly distributing the seed in suitable quantity. After passing the feeder the uncrushed kernels drop on to a deflecting

FIG. 217.



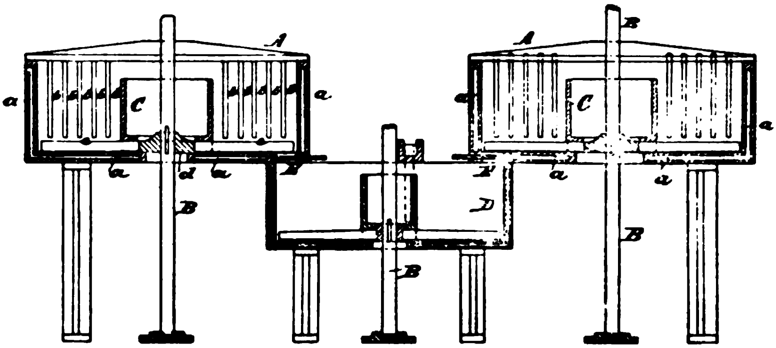
CRUSHER ROLLS FOR COTTON SEED.

plate, also made adjustable, the supports of which are shown in the cut by angle irons on the inside of the frame, and are carried between the rolls. The rolls are kept clean by weighted steel scrapers, which are also made as a deflector for the meal, which drops to the next deflecting plate and passes through in succession each succeeding pair of rolls. The meal leaves the rolls in very thin flakes, every sack or oil-cell completely crushed.

Cold pressure produces a very good salad oil, and this is the method generally pursued in Marseilles and other European cities for the first pressure, after which the residue is subjected to a second warm pressure. In this country, however, warm pressure is generally preferred. The meal is heated in a meal heater for 15 to 20 minutes to 204.4° to 215.3° F. The accompanying illustrations (Figs. 218, 219, 220, and 221) show the system of heating meal and forming cake preparatory to pressing, patented by John H. Vaile, of Dayton, Ohio, and manufactured by the Stillwell-Bierce & Smith-Vaile Co., of Dayton, Ohio. Fig. 218 is a central sectional view in front elevation; Fig. 219 an end elevation of the same, with the storage tank in central section. Fig. 220 is a front elevation, including a modification of the apparatus. Fig. 221 is a sectional end elevation of Fig. 220.

Referring now to Figs. 218 and 219, *A A* are cylindrical cooking tanks heated in any suitable manner, but preferably surrounded by a steam-jacket, to form steam spaces *a* upon the sides or bottom, or both, into which live steam is introduced to heat or cook the meal, by which it is brought into that condition in which it will most readily yield its oil when pressed. These cooking tanks have two or more rows of vertically suspended blades or knives *b*, properly supported, and under which two or more blades or knives *c*, preferably segmented in shape and attached to a hub *d*, keyed upon a vertical revolving shaft *B*, revolve just above the bottom of the tank. Also secured to the hub *d* is a central cylinder *C*, between the periphery of which cylinder and the wall of the tank the meal to be cooked is confined. As seen, there are in this instance two of these cooking tanks, properly supported, and with their edges projecting over a third tank *D*, resembling the other tanks, which is termed the "storage tank." *E E* are suitable traps in the bottoms of the tanks *A* opening into the tank *D*, through which the meal, when cooked, is drawn from the tanks *A* into the storage tank *D*.

FIG. 218.

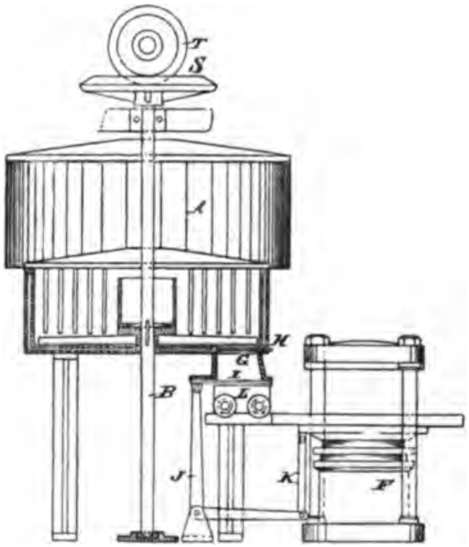


CENTRAL SECTIONAL VIEW.

F (Fig. 219) is a press for forming the cake. *G* is a trap in the bottom of the tank *D*, which trap is closed at its upper end by a gate or slide *H*, to be operated by hand, and its lower end by an automatic gate or slide *I*, connected by a bell-crank *J* and link *K* to the plunger or platen of the press *F* in such a manner that the press ascends to form a cake; the slide *I* is drawn back, permitting a charge of meal to be deposited in the filling hopper *L*, which is placed under the trap *G*. As the press descends the slide *I* is closed and the meal hopper, which is preferably on rollers, is passed over the meal box of the press for the purpose of filling the same with a charge of meal, after which it is drawn back under the trap *G*, as before, and so the operation continues rapidly and without interruption.

By the employment of the cylinder *C*, which may be either stationary or may revolve, it will be readily understood that the meal in the cookers is kept of equal depth or density throughout, and will not, by the action of the stirrers *C*, be piled up against the outer walls of the cooker, and thus it is evenly subjected to the action of the heat and becomes thoroughly cooked throughout. By means of the vertical knives *b* the formation of what are known as "water balls" is prevented, or, if they are formed, they are readily broken up. From this arrangement it will be understood that when the contents of either of the tanks *A* are cooked they are at once drawn off into the storage tank *D*, to the jacket of which only a sufficient amount of steam is admitted to keep up the proper degree of heat without cooking, and the cooker is again filled. In the meantime the meal is being drawn off from the storage tank and supplied to the forming press, and thus the storage tank would be emptied before a second supply of meal would be cooked if it were not for the other cooker *A*, which by this time is ready to be emptied into the storage tank, and so the

FIG. 219.

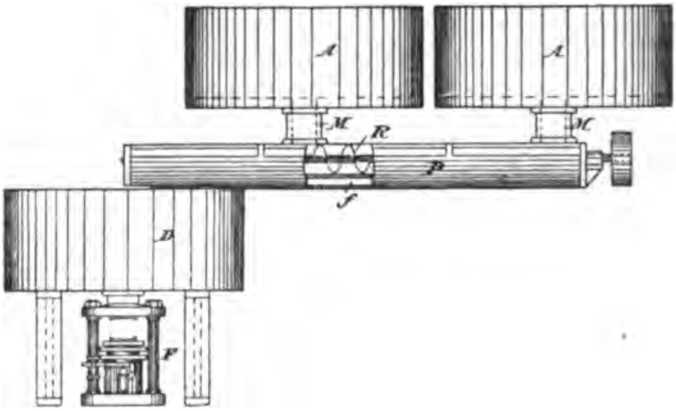


END ELEVATION, WITH STORAGE TANK IN CENTRAL SECTION AND CAKE-FORMING PRESS.

storage tank is kept constantly supplied, while the cookers *A* are intermittently discharged into it, and so loss of time and danger of improperly cooking the meal are absolutely prevented.

By reference to Figs. 220 and 221 the modification referred to will be found illustrated. It consists merely in locating the cookers *A* so that they discharge through traps *M*, closed by slides *N*, into a conveyer chamber *P*, surrounded by a steam-jacket to form a steam space *f*, and supplied with a constantly revolving, substantially horizontal screw conveyer *R*. This conveyer chamber extends over and opens into the storage tank *D*. By this means the cooked meal is conveyed from the cookers *A* into the storage tank, as will be readily understood.

FIG. 220.



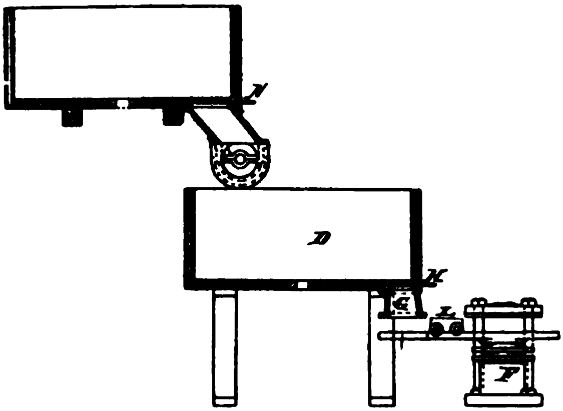
MODIFICATION OF THE APPARATUS. FRONT ELEVATION.

It is not essential that the slide of the trap *G* should be automatic; but where it is, as shown in Fig. 219, the gate *H* is left constantly open as long as the press is in operation; but, as seen in Fig. 221, the lower gate *I* may be dispensed with and the gate *H* operated by hand to charge the hopper *L*.

The steam connections can be made from the boiler in the usual or any suitable manner, and the shafts *B*, as seen in Fig.

219, may be driven by beveled pinions *S T*, the latter of which may be upon a line shaft.

FIG. 221.

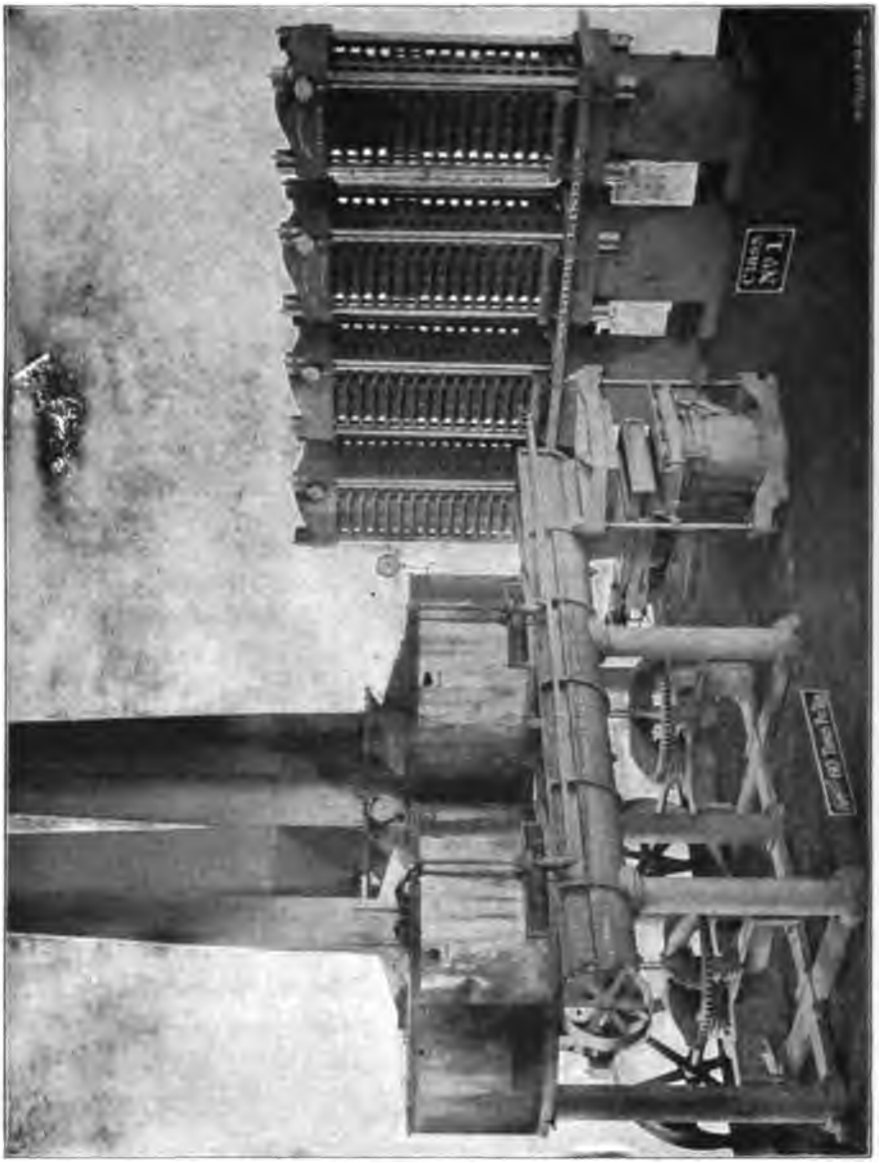


SECTIONAL END ELEVATION OF FIG. 220.

Fig. 222 illustrates the Smith-Vaile system of cooking the meal and forming the cake preparatory to pressing, known as the direct conveyer system. In this process the charging heater is done away with, the cooked meal being dumped into an iron conveyer box and carried direct to the charging hopper immediately over the cake former. It possesses the advantage of taking up less room than the combination triple heater system, and can be extended to any capacity of mill by simply adding another heater with the necessary length of conveyor. The heaters are made in one solid casting, and are steam-jacketed on bottom, top, and sides with asbestos faced hair felt, held in place by an outside lagging of Russia iron. Each heater is provided with patent charging hoppers of sheet iron, with hinged and sliding gate. The top of the heater is made in two sections, one of which is hinged and can be raised at the will of the heater-man to enable him to satisfy himself of the condition of the charge, or to change the stirrer knives when the heaters are not in operation.

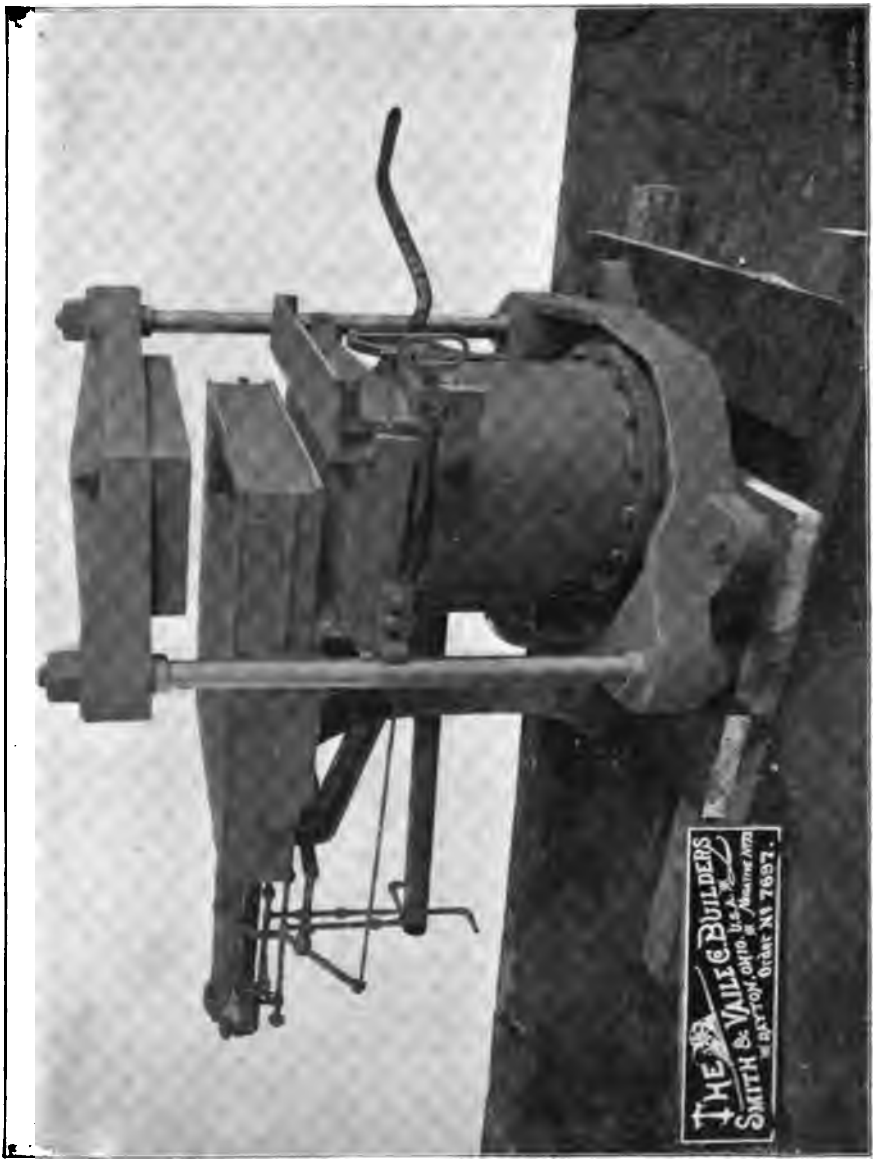
Fig. 223 shows the Smith-Vaile improved steam cake former.

FIG. 222.



SET OF THE SMITH-VAILE 72-INCH HEATERS AND CHARGING HOPPERS, WITH AUTOMATIC CAKE FORMER AND FOUR STEEL BOX PRESSES.

FIG. 223.



THE SMITH-VAILE IMPROVED STEAM CAKE FORMER.

It is used for shaping or forming the meal coming from the cooking heaters into cakes, before it is placed in the boxes of the press and subjected to hydraulic pressure. The ram is eighteen inches in diameter, and is provided with an automatic cushioning device for the drop or return stroke. On top of the ram is placed the meal box, which is filled by the sliding meal carriage operated by a small steam cylinder in the rear. This meal carriage runs under the charging hopper, which receives the cooked meal direct from the heaters. The operation of the meal carriage is very rapid, and by the use of this former a fifteen-box press can be filled in three minutes.

The heated meal is placed in woolen bags, each holding sufficient seed for a cake. The bags are then placed between horse-hair mats backed with leather, having a fluted surface inside to facilitate the escape of the oil under the hydraulic pressure, amounting to 169 tons. With the most improved presses the hair mats are, however, done away with. The bags remain in the press seventeen minutes, the solid "oil cake" of commerce remaining behind. This cake forms a superior feed for cattle, horses, sheep, and especially swine. It is nutritious, easily digested, and fattening. Its composition varies even more largely than does the seed from which it is made. The following analyses by the "American Analyst" show this variance, and also show that the chief variation occurs as between decorticated and undecorticated seed.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
	American decorticated.	American undecorticated.	Georgia.	Georgia.	South Carolina.	German.	English.	English, rancid.	Brazilian.
Water	9.3	11.5	10.1	11.2	9.4	9.2	8.5	14.6	9.7
Cotton-seed oil	16.4	5.1	15.4	13.9	14.5	5.6	13.7	10.8	14.8
Albuminoids and ammonia making compounds	42.1	23.2	30.7	34.2	37.3	40.5	38.8	34.3	40.9
Gum, sugar and soluble starch	2.2	1.1	2.4	1.7	2.1	2.2	1.9	3.3	2.2
Cellulose, starch, and resin	14.6	32.5	20.9	18.8	23.6	17.7	15.9	15.7	15.9
Lignin	8.2	20.4	13.4	13.7	6.3	17.5	14.3	14.4	9.9
Mineral constituents, phosphate of lime, silica, alumina, iron, magnesia, potash, soda, etc.	7.2	6.2	7.1	6.5	6.8	7.3	6.9	6.9	6.9

Cotton-seed cake is of a rich golden color, quite dry, and has a sweet, nutty, oleaginous taste. When ground to the fineness of corn-meal it is known as "cotton-seed meal," and in that form is frequently used for fertilizing purposes.

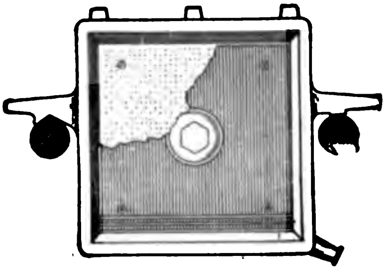
The oil is chiefly pressed in winter, though some mills are operated during the summer. The crude oil is either refined or shipped in tanks holding from 36,000 to 45,000 lbs. each. When the oil is shipped north in winter it usually becomes solidified. In order to get it out of the tanks they are placed on switches, and a jet of steam is introduced into the tank and the oil gradually melted out. Another method consists in covering the tank with wood, forming a chamber into which exhausted steam is introduced. Gutters are provided along the railroad tracks, into which the oil flows and is conducted into the receiving tanks. From the latter it is pumped into large receivers called scale tanks, where the crude oil is weighed.

Refining process. After weighing, the oil is pumped into refining kettles. They are of various sizes, the largest being 20 to 25 feet deep and 15 feet in diameter. These tanks are furnished with steam-coils for the purpose of heating the oil, and with mechanical agitators. A solution of caustic soda is used for refining. This solution is made from 10° to 20° Bé. in strength, and varying quantities are used according to the nature of the oil operated upon. The lye, at the temperature of 60° F., is fed slowly by perforated pipes extending over the surface of the oil and distributing uniformly. After the addition of the caustic soda, the mixture is agitated and kept at a temperature of 100° to 110° F. The contents of the tank are then allowed to stand six to thirty-six hours, when the solid matters, soap and substances precipitated by the caustic alkali gather at the bottom. This mixture is called "foots," and is used for making soap. The yellow oil resulting by this process is further purified by being heated and allowed to settle again, or by filtration, and is called *summer yellow oil. Winter yellow* oil is made from the above material by chilling it until it partially crystallizes and separating the stearin formed, about

25 per cent., in presses similar to those used for lard. This *cotton-seed stearin* is used for making butterine and soap.

For the purpose of producing *white oil* the yellow oil obtained as above is treated with from 2 to 3 per cent. of fuller's earth in a tank furnished with a mechanical agitator. When the fuller's earth has been thoroughly mixed with the oil, the whole is sent to the filter-press. The fuller's earth has the property of absorbing or holding back the yellow coloring matter, so that the oil which issues from the press is almost white. This white oil is chiefly used for making *compound lard.*

FIG. 224.



Many filter-presses have been devised and patented; of these only the filter press, Figs. 224, 225 and 226, constructed by the Stillwell-Bierce & Smith-Vaile Co., of Dayton, Ohio, may be mentioned. It is designed for filtering and clarifying cotton-seed and linseed oils, effectually removing all the foots and yielding a perfectly clear oil. The plates, Fig. 225, have perforated plates on top, or are made so that the filter-cloth rests on the corrugations of cast-iron plate, if desired. The plates have lock-nut in centre to grip perforated plate and cloth, or to grip simply the cloth, and are provided with relief valve on feed-pipe, drain trough and floor pan, and quick opening and closing movement.

FIG. 225.

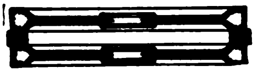
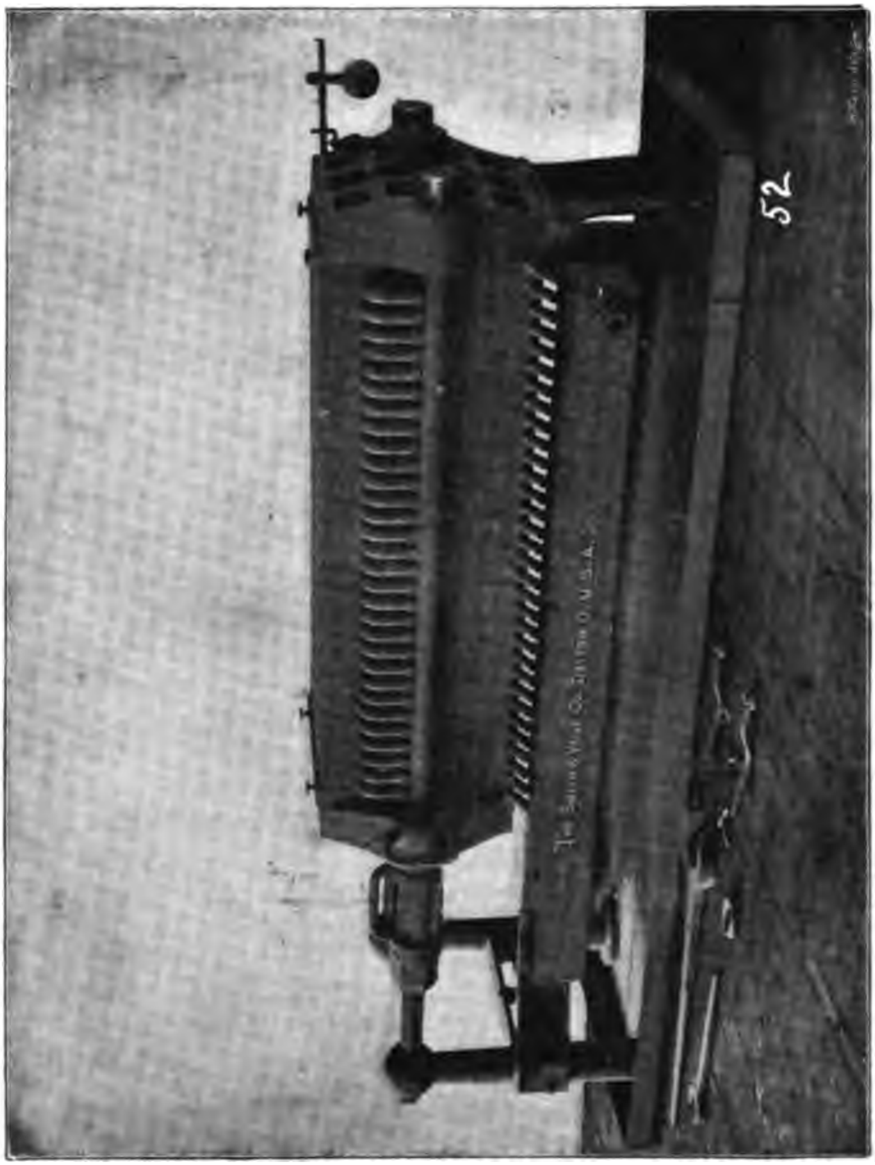


FIG. 226.



SMITH-VAILE FILTER PRESS.

Bleaching of cotton-seed oil may be successfully effected, according to Jolles and Wild, by the following process: Dissolve 50 parts of potassium dichromate in 500 parts of water and 100 parts of sulphuric acid, and add, with constant stirring, 6.5 pounds of this solution to every 100 pounds of cotton-seed oil, previously heated to 140° F. Keep the stirring apparatus in operation for 1 or 1½ hours longer. Then allow to settle; next wash with water until the bitter taste disappears, then heat to 212° F., mix with 1 per cent. of animal charcoal, stir well, and filter.

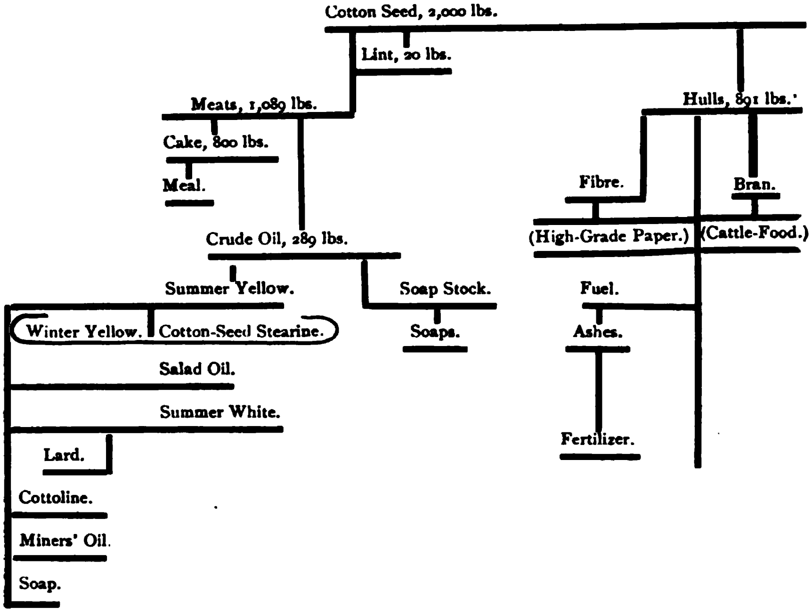
The cotton-seed oil produced in the English, and some of the German, mills differs essentially from the American product. In both countries Egyptian seed is exclusively used. To obtain a greater yield of oil the seed, previous to and during pressing, is strongly heated, whereby the crude oil acquires a disagreeable and acrid odor and an intense brown coloration.

Crude cotton-seed oil is thickly fluid, twenty-eight to thirty times less fluid than water, and has a specific gravity of 0.9283 at 68° F., 0.9306 at 59° F., and 0.9343 at 50° F.

According to the quality of the oil, palmitin is separated between 54° and 43° F. The oil solidifies at 28.5° to 27° F. In taste and odor it resembles linseed oil, and as regards other properties it is an intermediate between drying and non-drying oils.

Refined cotton-seed oil is of a straw or golden-yellow color, or, occasionally, nearly colorless. By subjection to cold and pressure a certain proportion of stearin is separated, the melting point of the residual oil being correspondingly lowered. Refined cotton-seed oil is usually very free from acid, and when properly prepared is of a pleasant taste, and admirably adapted for edible and culinary purposes, for which it is now extensively employed, both with and without its nature being acknowledged. It is much used as a substitute for and an adulterant of olive oil. From North America alone about 6,000,000 gallons of refined cotton-seed oil are annually shipped to the ports of the Mediterranean and France. The solid fat obtained by subjecting the oil to cold and pressure is brought into commerce under the name of *cotton-stearin* or *vegetable margarin.*

The following diagram, given by Mr. Robert Grimshaw,* is of interest, illustrating the gradual division of the products from a ton of cotton-seed:



The specific gravity of refined cotton-seed oil ranges from 0.922 to 0.926 at 59° F., and the solidifying point from 32° to 30° F. It consists of 30 to 34 per cent. stearic acid, and 66 to 70 per cent. oleic acid.

Cotton-seed oil differs from other fat oils in that when treated with *sulphuric acid* of 1.76 specific gravity it acquires a deep red to brown color, and on gently heating the mixture forms a combination soluble in water. With concentrated acid of 1.820 specific gravity, the mixture of both thickens in the cold to a brown somewhat olive-green mass in twenty-four hours.

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* Industrial Application of Cotton-seed Oil. Read at the meeting of the Franklin Institute, Dec. 19, 1888.

If the readily saponifiable portion of the oil be heated with 3 or 4 per cent. of anhydrous sulphuric acid for a few hours to 212° F., a black-blue body is formed, which, after washing with water and purifying with ether, yields a dark blue coloring matter—*cotton oil blue* $=C_{17}H_{24}O_4$—which dissolves sparingly in alcohol, but more readily in ether. In concentrated sulphuric acid it dissolves with a purple color. By water it is precipitated without change. Experiments to render this coloring matter useful for industrial purposes have thus far failed.

Nitric acid does not change the color of cotton-seed oil. Treated with an addition of granulated copper it becomes reddish yellow to brownish yellow in a quarter of an hour; after twelve hours the oil is pasty-fluid, and in twenty-four hours very thickly-fluid, frequently with some trifling separation of elaïdin.

Nitric acid of 1.4 specific gravity when mixed with the oil gives a red brown coloration, which is also clearly perceptible in mixtures of the oil with other oils, so that this reaction may serve for the detection of cotton-seed oil in other oils.

Fuming nitric acid immediately colors the oil brown on the point of contact and thickens it in an hour.

Soda and potash lyes of 1.04 specific gravity give no emulsion; the fluids separate. Saponification only takes place by frequent shaking in twenty-four hours.

Lyes of 1.20 specific gravity give an emulsion, the surface of which assumes a blue-violet color after long contact with the air.

Concentrated lyes of 1.33 specific gravity rapidly saponify the oil to 1.85 per cent. of a non-saponifiable liquid hydrocarbon, which can be extracted with petroleum-ether.

Liquid ammonia shaken with the oil gives a slightly greenish-yellowish-white mixture.

Alcoholic solution of silver nitrate boiled with the oil one-half minute, and then allowed to rest, is but very little reduced, the oil acquiring a trace of a brownish hue.

Solution of zinc chloride colors the oil brown on heating.

Basic acetate of lead when mixed with cotton-seed oil gives, according to Bradford, a red coloration. In case of a simple mixture with another oil this coloration alone may serve for the detection of cotton-seed oil in other oils.

Of *iodine* up to 38 per cent. is dissolved by cottonseed oil.

Saponification number of the oil	194–195
Iodine number of the oil	106–107
" " of the fatty acids	112–115
Fusing point of the fatty acids	98.6°–100.4° F.
Solidifying point of the fatty acids	90.5° F.

While it is a substitute or adulterant for olive oil, cotton-seed oil is used in the manufacture of soap, by painters, and for lubricating purposes. It is thought that, in time, the prejudice now existing against cotton-seed oil in this country will be overcome, and our people, like those of Europe, take to cooking their food in oil instead of using lard. That there is a growing demand for cotton-seed oil for table use and culinary purposes is evidenced by the increased business of merchants who make a specialty of filling fancy bottles with cotton-seed oil. It has met with favor wherever introduced, and when a consumer is persuaded to try one bottle there is no difficulty in making repeated sales to the same person. Every article of commerce requires time before it is accepted by the public, but good progress has been made in the introduction of cotton-seed oil, and the time is not far distant when it will be ahead of most all competitors.

The United States furnish annually over 6,000,000 tons of cotton-seed, which yield more than 25,000,000 gallons of oil, 250,000 tons of cake, and 3,300 tons of hulls and residues.

Egypt furnishes annually about 250,000 tons of seed.

Closely allied to the varieties of *Gossypium* are the following related species, the seeds of which are also used for the expression of oil very much resembling cotton-seed oil.

2. *Bombax malabaricum*, *Dec-Bombax heptaphyllum*, Roxb. or Malabar wool tree, a large tree with digitate leaves and large flowers. The fruit is a longish woody capsule with numerous dark brown seeds enveloped in a short elastic wool, which on account of its shortness is only suitable for stuffing and upholstering, and is called *silk-cotton*. The tree is indigenous to India, where it is known as *Pulà-maram*, *Pinna-buruga*, and *Simbal*.

3. *Eriodendron anfractuosum*, W. = *Bombax pentandrum*, Linn., the common bombax or wool tree, indigenous to the East and West Indies. The lint enclosing the seed is also used for stuffing mattresses, furniture, etc. The seed contains 25 per cent. of a thickish oil, which when obtained by expression is of a dark brown color, while when obtained by extraction it is of a pale yellow color like castor oil, and may be used for edible and culinary purposes. The oil is known as *Kopak* or *Kapok oil*. The oil obtained by expression is brought into commerce for the manufacture of soap. It has a slight, not disagreeable, odor and taste, saponifies almost completely, and generally resembles cotton-seed oil. The oil has recently been examined by Robert Henriques with the following results:

Specific gravity of the oil at 64° F.	0.9199
Specific gravity of the fatty acids	0.9162
Fusing point of the fatty acids	84.2° F.
Solidifying point of the fatty acids	73.4–75.2° F.
Saponification number of the oil	181
Saponification number of the fatty acids	191
Medium molecular weight of the fatty acids	293
Iodine number of the oil	116
Iodine number of the insoluble fatty acids	108
Hehner's number	94.9

4. *Hibiscus cannabinus*, Linn., an annual or perennial plant which is much cultivated in India, where it is called *Ambarée*, *Sunn-okoa* or *Bun-Kupasi*. The capsule is roundish, the seed flat. The latter contains 25 per cent. of oil, which is used for edible and culinary purposes, as well as for burning.

5. *Tespesea populnea*, Cor. = *Hibiscus populneus*, Roxb., in-

diginous to India, where it is known as *Porush*, and to Ceylon where it is called *Soorigagaha*. The pubescent seed contains a dark red oil called at the Cape Verd Islands "*Huile amère*," and is used for medicinal purposes.

Sterculiaceæ (*Columniferæ*).

1. *Stinking bean oil* (*Stinkbaumöl, G.*) called *telamboo* in Ceylon, is obtained from the woody fruit of *Sterculia fœtida*, Linn., a tree indigenous to the West Indies, Burmah, Ceylon, etc. Each fruit contains ten to fifteen black seeds, with about twenty-five per cent. of oil. The oil has a pale-yellow color, is thickly-fluid at 68° F., and has a specific gravity of 0.923 at 59° F. At 37.4° F. it becomes thick, and at 32° F. separates stearin. It turns rancid very rapidly. It is used in the manufacture of soap, and as lamp oil.

2. *Sterculia acuminata*, P. R., yields the oleaginous "*gura nuts*."

3. *Herietaria littoralis*, Dryand, known on the coast of Bengal, in the West Indies, etc., as "*doengngoe kontol*" and as "*kannatso*." The spicy seed contains an oil which is utilized in the Antilles.

Tiliaceæ (*Columniferæ*).

Tilia parvifolia, *T. ulmifolia*, the linden, of which the two specimens here mentioned occur chiefly in Europe, is a stately tree from 40 to 100 feet high, and has a soft white wood, fibrous bark and alternate, petiolate, heart-shaped serrate leaves. Different species of linden are also known as *lime tree*, *white-wood* and *bass-wood*. The seed contains up to 58 per cent. of a fat oil—*linden seed oil*—resembling in color and odor the best quality of olive oil. It is free from every bitter and aromatic tang, and does not become rancid or at least only with great difficulty. It does not solidify when exposed to great cold, does not change, and cannot be frozen in a freezing mixture of —5.8° F.

Camelliaceæ (*Lamprophyllæ*).

1. *Tea seed oil* (*Theesamenöl*, G.; *huile de thé*, F,) from the seed of *Camellia theifera*, Griff., the tea plant. The seed contains thirty-five per cent. of a somewhat limpid, tasteless, inodorous oil of a straw to amber color, which resembles olive oil. Its specific gravity is 0.9270 at 59° F. At 39.0° F. it forms an emulsion, and solidifies only below 23° F. It is scarcely soluble in spirit of wine and very sparingly in ether. Chemically it consists of 25 parts of stearin and 75 parts of olein. In China it is used as a table and lamp oil and in the manufacture of soap, for which it is specially well adapted, yielding a beautiful, hard product. Tea oil has been used in China for a very long time, but has only been recently introduced in commerce.

2. *Camellia oleifera*, Abel = *Thea oleosa*, Lour., *oil-yielding tea-plant*. The oil expressed from the seed forms a commercial article in China, where it is known as *Cha Yau* (tea oil). It was formerly erroneously considered as derived from the tea-plant.

The seed freed from the testa and extracted with ether yields 44 per cent. of an odorless, yellow, somewhat gummy oil, which, however, is not suitable for culinary purposes on account of its disagreeable tang, and 10 per cent. of a glucoside giving the principal reactions of saponin.

As regards color, transparency and mobility, as well as its reactions, the oil resembles olive oil. To obtain the oil the seed is pulverized, strongly heated and expressed. The specific gravity of the oil at 59° F. is 0.9175. It consists chiefly of olein, and therefore yields but little sediment when cooled to —8.6° F. It contains no free acid, and consequently is well adapted for lubricating fine machinery.

The pulverized press-cake of *Camellia oleifera* serves in China for the removal of grease stains and is known as *Cha-tsai-fau*. Its dust provokes sneezing. Both contain the same saponin-like substance mentioned above, which may be obtained from the mass extracted with ether as a white amorphous powder by repeated solution in 84 per cent. alcohol and subsequent evaporation. On heating with dilute hydrochloric acid it splits into glucose (sugar) and sapogenin.

3. *Camellia drupifera*, Lour., the drupe-bearing tea-plant, yields an oil used for household purposes.

Myrtaceæ-Lecythideæ (*Myrtinæ*).

Brazil-nut oil or *Para-nut oil* (*Paranussöl, Juviaöl*, G.; *huile de Castanheiro*, F.), from the fruits of *Bertholletia excelsa*, Humb., the Brazil-nut tree, indigenous to the forests of Para, and cultivated in South America, Guiana, and Brazil. The kernels contain sixty to sixty-seven per cent. of oil and are composed of

Oil	65.45 p. c.	
Organic substances,	22.82 "	
albuminous substances therein		15.20 p. c.
Ash	4.23 "	
phosphoric acid therein		2.25 "
Water	7.50 "	
	100.00 "	

The oil has a pale yellow color, is tasteless and inodorous, with great tendency to become rancid. It has a specific gravity of 0.9185 at 59° F., becomes turbid at 35.5° F., and solidifies to a semi-solid white mass at 34.0° F. It is pressed in South America, where the fresh oil is used as a table oil; otherwise it is employed in the manufacture of soap and as lamp oil.

Nitric acid containing nitrous acid, and of 1.30 specific gravity, does not color the oil, but solidifies it in less than a quarter of an hour to a yellowish-white mass of the consistency of butter.

A mixture of equal parts of *nitric acid*, *sulphuric acid*, and *water*, mixed with equal parts of oil, gives a brownish-yellow coloring.

An addition of one drop of *concentrated sulphuric acid* to twenty drops of the oil gives first a red, and then a reddish-brown color, resembling that of syrup, the oil thickening very rapidly.

Zinc chloride gives a rose color.

2. *Lecythis ollaria*, L., a very tall tree common in the Brazilian forests. The nuts are as large as the human head and contain an oil known as "*sapucaya oil*," which is much used in South America.

3. *Barringtonia speciosa*, Linn., and

4. *Barringtonia racemosa*, Linn., indigenous to Java and the Moluccas, yield good lamp oil.

Combretaceæ (*Calycifloræ*).

1. *Jungle almond oil* (*Catappaöl*, G.; *huile de Badamier*, F.) extracted from the fruit of *Terminalia catappa*, L., a large tree of the East Indies, also cultivated in Hindostan, Mauritius, etc. The nuts have a taste resembling that of almonds, and contain twenty-eight per cent. of oil used as a table oil. It excels almond oil as regards flavor and mildness, and has the further advantage of keeping well. It is of a pale yellowish color and entirely inodorous. Its specific gravity is 0.918 at 59° F. It is chiefly composed of stearin and olein, stearin being separated at 41° F.

2. *Chebula oil*, a thinly-fluid colorless oil obtained from the nuts of *Terminalia chebula*, Retz, a tree indigenous to Central and Southern India. The nuts yield less oil than those of the preceding species.

3. *Terminalia bellerica*, Roxb., is, like the preceding species, indigenous to the East Indies. The oil expressed from the nuts behaves in the same manner as mastic oil (see page 424), a pale green fluid oil and a white fat of the consistency of butter being separated.

The fruits of the above three varieties of *Terminalia* are known in commerce as "*myrobalans*," and on account of their tannin, of which they contain about twenty per cent., are used in tanning and dyeing.

Capparideæ (*Rhœadeæ*).

The fruit of *Cleome viscosa*, Linn., a herbaceous shrub indigenous to tropical India, contains about nine per cent. of a very limpid oil with a specific gravity of 0.9080 at 59° F. It is known in Hindostan as "*Hoorhoorya.*"

Cruciferæ (*Rhœadeæ*).

1. ***Rape seed and colza oils.*** The oils extracted from the seed of the different species of *Brassica* closely resemble one another, and in Great Britain and the United States are generally called indiscriminately rape seed or colza oils. There are, however, several varieties of the rape plant which have been developed by successive cultivations, and on the Continent of Europe the oils obtained from the various kinds of seed are generally known by different names. According to the original plant, the following distinctions have to be made:

1. *Colza oil or coleseed oil* (*oleum brassicæ; Kohlsaatoel*, G.; *huile de colza*, F.) from *Brassica campestris*, Linn.
2. *Rapeseed oil* (*oleum napi; Rapsöl*, G.; *huile de navette*, F.) from *Brassica campestris var. napus*, or *Brassica napus oleifera.*
3. *Rubsen oil* (*oleum raparum; Rübsenoel*, G.; *huile de rabette*, F.) from *Brassica compestris var. rapa*, or *Brassica rapa oleifera.*

These oils are further subdivided into:

1. *Summer rubsen oil*, from *Brassica rapa annua*, or summer rubsen.
2. *Winter rubsen oil*, from *Brassica rapa biennis*, or winter rubsen.
3. *Summer rape-seed oil*, from *Brassica napus annua*, or summer rape.
4. *Winter rape-seed oil*, from *Brassica napus biennis*, or winter rape.

To the naked eye the seeds of the different species of *Brassica* appear as small round grains with dark almost smooth testa, a light chalaza and lemon-yellow embryo with two cotyledons and radicles about 1 millimeter long. The seeds of the different species are not readily distinguished by the eye. The seed of *Brassica napus* is mostly bluish black, that of *B. campestris* red-brown and that of *B. rapa* nearly black. As a rule the seed of *B. campestris* is larger than that of the other two plants, which are about 2 millimeters in diameter, the rubsen seed being, however, smaller than rape-seed.

It has, however, been established by accurate tests that by reason of nunerous transitions the seeds of these three varieties of *Brassica* cannot be distinguished from each other either by measurement or with the assistance of the microscope, so that in fact no distinct characteristics by which colza, rape and rubsen seeds may be recognized exist.

J. Schroeder has endeavored to base the distinction of the three kinds of oil seeds upon the determination of specific gravity of a number of seeds, but more extensive experiments have to be made before this method can be accepted as a guide.

100 seeds weigh.	Grammes.	Average.
Brassica campestris biennis—colza	1.869–1.978	1.901
" *rapa biennis*—rubsen seed	2.055–2.241	2.142
" *napus biennis*—rape seed	4.538–4.786	4.667

The composition of the seeds of the different species of *Brassica* is as follows:

	Brassica rapa.		
	Summer rubsen, Silesia, per cent.	Winter rubsen, fresh seed, Silesia, per cent.	Winter rubsen, older seed, Hungary, per cent.
Oil	33.82	35.25	38.50
Organic substance	52.63	52.59	53.25
nitrogen therein	2.41	2.50	3.11
Ash	3.40	3.26	3.90
Water	10.15	8.90	4.35
	100.00	100.00	100.00

	Brassica napus.		
	Summer-rape, Silesia, per cent.	Winter-rape fresh seed, Pommerania, per cent.	Winter-rape seed two years old, Silesia, per cent.
Oil	35.00	36.80	39.25
Organic substance	51.48	49.30	51.14
nitrogen therein	2.20	2.50	4.20
Ash	4.12	4.80	4.36
Water	9.40	9.10	5.25
	100.00	100.00	100.00

	Brassica campestris.		
	Maine-Loire colza, per cent.	Belgian colza, per cent.	Alsace colza, per cent.
Oil	33.22	38.90	43.00
Organic substance	58.36	54.64	42.10
albuminous substances therein	22.30	21.24	18.20
Ash	4.17	3.50	4.90
Water	4.25	2.96	10.00
	100.00	100.00	100.00

The ash of the three varieties of winter seed contains:

	Rubsen, per cent.	Rape, per cent.	Colza, per cent.
Potash	25.68	21.34	25.18
Soda	1.66	5.26	
Magnesia	10.57	11.96	11.39
Lime	9.20	14.63	12.91
Ferric oxide	1.46	2.84	0.62
Chlorine	0.43	—	0.11
Sulphuric acid	9.44	0.77	2.53
Silica	0.30	1.52	1.31
PHOSPHORIC ACID	41.26	41.68	45.95
	100.00	100.00	100.00

The average content of oil amounts in

Summer-rubsen and summer rape to	30–35 p. c.
Winter-rubsen and winter rape to	35–40 "
Winter colza to	35–45 "

The average yield of oil with warm pressure only is from

Summer seed	28 per cent.
Winter seed	33 "
Colza seed	36 "

The oils of the different species of *Brassica* are identical as regards their principal properties. Freshly pressed, they have a more or less dark brown-yellow color and are almost odorless; by storing for some time they deposit much mucus, and acquire a peculiar disagreeable odor and taste caused by sulphur combinations.

In a crude state the oils can be used only as lubricants. They have to be freed from mucus and albumen by refining, whereby they acquire a pale yellow color.

The specific gravity of the oils ranges from 0.9112 to 0.9175 at 59° F., and their solidifying points from 28.5° to 14° F.

The different varieties of oil possess the following properties:

Summer rubsen-seed oil is brownish-yellow, thickly-fluid, has a specific gravity = 0.9139 at 59° F., and at the same temperature is 15.1 times more thickly-fluid than water, and at 45.5° F., 22 times. At 17.6° F. the oil separates stearin and at 14° F. solidifies to a yellow-white butter.

Winter rubsen-seed oil is brownish yellow, has a specific gravity = 0.9154 at 15° F., and at the same temperature is 17.6 times more thickly-fluid than water and at 45.5° F., 22.6 times. At 24.8° F. it separates stearin and at 18.5° F. solidified to a white-yellow mass.

The refined oil is pale yellow and has a specific gravity = 0.9127.

Summer rape-seed oil is brownish-yellow passing into green-yellow. Specific gravity at 59° F. = 0.9147. At 59° F. it is 16.4 times more thickly-fluid than water, and at 45.5° F., 22.7

times. It separates stearin at 30.2° F., and at 24.8° F. solidifies to a greenish-yellow white butter.

Winter rape seed oil also is brownish-yellow, passing into greenish. Specific gravity at 59° F. = 0.9157, at 50° F. = 0.9184. At 59° F. the oil is 18 times more thickly-fluid than water and at 45.5° F., 22.4 times. It separates stearin below 30.2° F., and solidifies to a yellow-white mass at 28.4° to 26.6° F.

Freshly-pressed oil, on standing, separates mucus, becomes clear and the upper layers appear green-yellow, and the lower golden yellow. On heating to 392° F., it becomes green-yellow, acquires a stronger odor, decomposes at 662° F., and gases pass over which condense to a limpid, acid, yellow-green oil of a strong odor. The refined oil has a pale, wine-yellow color and a specific gravity = 0.9132.

In popular language rape seed oil is "fatter" than rubsen seed oil, which, however, refers only to its being more thickly-fluid.

Colza oil has a specific gravity = 0.9150, and when refined = 0.9136. In color it resembles winter rape-seed oil and is only somewhat more thickly-fluid. It separates stearin at 24.8° F., and at 21.2° F., solidifies to a yellow buttery mass.

Japanese cabbage oil has a deep-brown color and a disagreeable odor; its specific gravity at 59° F. is 0.914; it solidifies at 35.6° F.

The expanding power of the above-mentioned oils is almost the same; 1000 quarts of oil measured at 32° F. increasing 17.8 quarts when measured at 68° F.

All the oils are sparingly soluble in alcohol, 100 parts of the latter absorbing only 0.35 to 0.6 per cent.

As regards their chemical behavior the oils are almost identical. They readily absorb oxygen from the air and become rancid, thickening at the same time without drying,

There is scarcely any difference in their elementary composition:

	Rubsen Oil.	Rape Oil.	Colza Oil.
Carbon	77.21 per cent.	77.48 per cent.	77.34 per cent.
Hydrogen	13.36 "	13.03 "	13.11 "
Oxygen	9.43 "	9.50 "	9.55 "
	100.00 per cent.	100.00 per cent.	100.00 per cent.

The oils contain the glycerides of stearic acid, erucic acid = brassic acid $C_{22}H_{41}\left.\begin{matrix}O\\H\end{matrix}\right\}O$, and of an oleic acid which, according to Darby and Websky, differs from the ordinary oleic acid in not yielding sebacic acid $C_{10}H_{18}O_4$, by distillation.

Nitric acid of 1.180 specific gravity does not change the color of the oils. *Nitrous acid* containing *nitric acid* produces a reddish-yellow color.

Fuming nitric acid carefully poured into the oils produces on the point of contact a brownish-red coloring with a slightly green zone below.

Treatment with *nitric acid* and *starch* for the development of nitrous acid colors

Crude oil, reddish-brown in about an hour. After about twenty hours the oil solidifies to a more or less granular brownish mass. Generally the layer of oil does not appear uniform in consistency and color.

Refined oil, reddish-yellow with a more or less brownish shade. In about twenty hours the oil solidifies to a mass not darkly colored, and sometimes not uniform in consistency and color.

An addition of two drops of *concentrated sulphuric acid* to twenty drops of oil causes:

In crude oil, in dropping in, a green color with a brownish edge, and, on stirring, a green color gradually becoming darker and finally passing into a green-brown.

In refined oil a brownish-yellow color, which, on stirring, passes into a dirty greenish-brown color, the green being more pronounced according to the degree of refinement.

A mixture of equal parts of *concentrated sulphuric acid*, *nitric acid*, and *water*, shaken with an equal volume of oil, produces only a reddish-yellow coloring.

Five grammes of *sulphuric* acid added to 15 grammes of oil causes, according to Faisst and Knauss, an increase in the temperature from 14° C. to 69° C., and an addition of 7.5 grammes of 95 per cent. sulphuric acid to 15 grammes of oil an increase in the temperature from 17° C. to 54° C.

Zinc chloride stirred into crude oil produces first a beautiful blue-green color, which later on passes into a dirty green. Refined oil treated in the same manner becomes yellowish or, according to the degree of refinement, gray with a slightly greenish tinge.

Solution of nitrate of silver is reduced brown-red by both the crude and refined oils.

Potash lye, *soda lye*, and *liquid ammonia*, shaken with oil in the proportion of one to five, give, with crude, oil, a yellow emulsion, and, with refined oil, a yellowish to white emulsion, according to the degree of refinement.

In boiling the oils with *potash lye* or *soda lye*, potassium sulphate or sodium sulphate is formed in consequence of a sulphur combination in the oils which is not yet thoroughly understood. The presence of sulphur in these combinations is indicated by the blackening of solution of subacetate of lead or of nitrate of silver, and also by the formation of lead sulphide or silver sulphide.

This behavior is shown by all oils obtained from the *Cruciferæ*, and their presence in other oils can therefore be readily detected in the above manner.

The presence of cruciferæ oil is still more simply shown by boiling the oil with white lead plaster, the *emplastrum plumbi* of the druggist. The plaster dissolves in the oil, and by the formation of lead sulphide colors the oil brown to black.

The oils of the different species of *Brassica* are chiefly used for illuminating and lubricating purposes, refined oil being exclusively employed for the first.

The oils are but seldom employed in the manufacture of soap, since they saponify with difficulty, and soft soaps prepared from them break up on exposure to a slight degree of cold; the "foots" of the oil mills are, however, used in combination with other oils in the manufacture of soft soap.

The different oils have a disagreeable acrid taste, but by boiling with an addition of the potato-starch or fresh bread or of onions, may be converted into an oil for edible and culinary purposes. For 30 pounds of oil one pound of starch is used. The oil is heated in a boiler until the starch is carbonized, when it is allowed to rest and finally filtered.

The disagreeable taste may also be removed by an addition of sweet spirits of nitre, 25 drops to about 3½ ounces of oil.

The oils are readily and perfectly bleached, according to C. Puscher, by mixing 100 parts of the oils with 2 parts of a mixture of equal parts of 96 per cent. alcohol and sulphuric acid. Instead of partial resinification, the usual result when sulphuric acid alone is used, the sulphuric acid forms a uniform mixture with the oils; the mixture soon becomes turbid, blackens subsequently, and after standing 24 to 48 hours a small black deposit subsides, leaving the supernatant oil as colorless as water. To remove traces of sulphuric acid the oils, after decantation from the deposit, are shaken with a little water and allowed to rest.

The oils are subjected to many adulterations, and as enormous quantities of them are used, we give in the following some hints as to what constitutes good oil.

1. Refined oil must be of a pale wine-yellow color, clear, thoroughly refined, not rancid, and free from acid. It should form no sediment, burn with a bright white flame without a deposit of soot and without odor. It should be so completely refined that when compounded with one per cent. sulphuric acid no sediment is formed.

It should have a specific gravity of 0.9132 to 0.9112.

2. Crude oil—lubricating oil—should contain as high a percentage of fat as possible. It should have a consistency corresponding to the temperature of the season of the year, be free from particles of acid, resin, and mucus, and form no sediment. Its specific gravity should be 0.9153 to 0.9132.

The non-rancidity of the oil can be readily determined by taste and odor.

In regard to being "free from acid," this refers partly to the possible presence of sulphuric acid, due to bad washing after refining, and partly to free oleic acid. In the first case the oil fizzes and sputters in burning and rapidly carbonizes the wick, and in the other case deposits more soot. In both cases the oil, if used as a lubricant, attacks the lubricated portions of the machinery.

For sulphuric acid the oil is tested by shaking with water, allowing to settle, and testing the aqueous fluid with blue litmus tincture or with solution of barium chloride. The first is colored red and the latter produces a white precipitate of barium sulphate.

By shaking 5 parts by weight of oil with 20 parts by weight of diluted spirit of wine, the oleic acid passes into the alcoholic solution and its presence can be established by blue litmus tincture.

The oleic acid can also be quantitatively determined as follows: Shake 2 parts of the oil with 10 to 12 parts of 90 per cent. spirit of wine, mix the mixture with blue litmus tincture, and then add carefully, with constant shaking, normal soda lye until the blue litmus color reappears.

The cubic centimetres of normal soda lye used in the determination correspond to one degree of acid, and the latter to about 0.28 per cent. of oleic acid.

For a quicker method requiring less shaking, a determined quantity of oil is dissolved in a mixture of equal parts of spirit of wine and ether, compounded with litmus tincture and titrated with alcoholic normal potash or soda lye. One alkaline degree = 1 acid degree = 0.28 per cent. of oleic acid.

For the quantitative determination of olive oil, according to Burstyn, see *olive oil*.

Oils free from acid, shaken with a concentrated solution of soda or potash, separate, after resting, into two layers. If oleic acid is present, an emulsion is formed.

Rosaniline serves also for the detection of oleic acid in fats. In a free state it is a colorless base which, in combination with one equivalent of acid, yields purple aniline colors. By adding this base to oil containing free oleic acid or another free fatty acid, the change of color into red takes place and the rosaniline oleate formed is dissolved in all proportions by the neutral oil. It is best to add to the oil a few drops of a cold saturated solution of rosaniline in alcohol, and to heat the mixture until the alcohol is evaporated. If no free acid is present, the rosaniline separates from the uncolored oil; in the other case the oil is colored more or less intensely red.

Adulterations with foreign vegetable, animal, or mineral oils can be detected, with some experience, by the taste, but to ensure certainty the suspected oil has to be saponified.

Heat 3 parts of the oil in question with 2 parts of caustic soda and 20 to 30 parts of water. To accelerate saponification add some spirit of wine.

Rosin oil and mineral oils remain unsaponified and float upon the lye. The lye is evaporated to dryness and extracted with ether, which is evaporated in a tared flask and the latter weighed. The residue contains only the non-saponifiable oils, saponified oils being insoluble in ether.

By the above saponification the presence of other oils is also recognized.

Brassica oil gives a more or less yellowish soap, according to the degree of refinement.

Hemp oil a greenish brown-yellow soap.

Fish oil a reddish-colored soap.

Linseed oil a golden-yellow soap.

By the addition of 1 volume of *syrupy phosphoric acid* to 5 volumes of oil, $\frac{1}{1000}$ per cent. of fish oil can be shown by a red coloring which, later on, passes into black.

Chlorine colors the oil, in the presence of fish oil, first brown and then black.

The adulteration of refined oil with camelina or German sesamé oil is detected by the pale bluish-green coloring given to it by chlorine. In the presence of hemp oil the oil becomes brownish-green, and in that of linseed oil gray-green, the latter color disappearing again.

For the detection of the last three oils the elaïdin test is also reliable.

An addition of 1 part of *nitric acid* containing a little nitrous acid to 5 parts of oil scarcely changes refined oil, but if camelina oil be present the mixture assumes a reddish color, in the presence of hemp oil a greenish-brownish color, and in that of linseed oil, a greenish-yellow color shading somewhat into a brownish hue.

Saponification number of the oils	177–179
Iodine number of the oils	98–100
Iodine number of the fatty acids	97–99
Fusing point of the fatty acids	68–69.8° F.
Solidifying point of the fatty acids	60.8° F.

The different species of *Brassica* are cultivated almost everywhere. Although petroleum has largely taken the place of the oils of the different species of *Brassica* for illuminating purposes, they nevertheless hold their price, since cultivation is more restricted, and large quantities of the oils are used for lubricating purposes. In Germany not sufficient seed is raised to cover the demand, and large quantities of it are imported from Austria, Hungary, Galicia, Roumania, Russia, etc., the crude oil being exported to England, America and Paris, though France produces almost enough for home consumption.

4. The seed of *Brassica napobrassica*, Miller—rutabaga or Swedish turnip—yields an oil like rape oil, which is known as *rutabaga oil* (*oleum napobrassicæ*). It has a specific gravity of 0.916 at 59° F.

5. *Black mustard seed oil* (*oleum sinapis nigri—Schwarzsen-*

föl, G.; *huile de moutarde noire*, F.) is obtained from the seed of *Brassica nigra*, Koch (*Sinapis nigra*, Linn.). The percentage of oil varies between 15 and 25 per cent., while the seed of the closely allied sarepta mustard (*Sinapis juncea*, Linn.) contains as much as 30 per cent. of oil.

	Black mustard.		Sarepta mustard.	
Oil	22.20 p. c.		28.45 p. c.	
Organic substances	66.81 "		58.46 "	
protein substances therein		20.52 p. c.		28.60 p. c.
potassium myronate "		1.68 "		0.61 "
Ash	4.21 "		5.74 "	
Water	6.78 "		7.35 "	
	100.00 "		100.00 "	

The ash of black mustard contains:

Potash	12.36	per cent.
Soda	6.09	"
Magnesia	14.38	"
Lime	17.34	"
Ferric oxide	1.14	"
Chlorine	1.38	"
Sulphuric acid	7.14	"
Silicic acid	2.78	"
Phosphoric acid	37.39	"
	100.00	"

The oil cakes from black mustard are used for the preparation of mustard and mustard paper, while the oil cakes from Sarepta mustard, which is peeled before pressing, come into commerce as a pale yellow meal.

Brassica juncea is indigenous to India, but is largely cultivated in Sarepta, Russia, one single firm alone exporting nearly 2,000,000 pounds of seed annually. In Russia the oil is used as a table oil.

Both oils contain stearic acid, erucic or brassic acid, and an oleic acid.

Black mustard-seed oil has a dark yellow-brownish color, a mild flavor, and slight mustard odor. It is 15.6 times more thickly fluid than water, has a specific gravity of 0.917 at 59° F., solidifies at 0.5° F., and is soluble in 4 parts of ether and in 1000 parts of spirit of wine.

An addition of 2 or 3 drops of *concentrated sulphuric acid* of 1.84 specific gravity to 20 drops of oil colors the latter bluish-green with brown stripes, the color passing later on into brown.

Sulphuric acid of 1.72 specific gravity, mixed with equal parts of oil, colors it blue-green, the color remaining pure about five minutes.

Nitric acid containing some nitrous acid colors the oil dirty brownish-yellow; fuming nitric acid, reddish. With the elaïdin test the oil solidifies in about 18 hours.

Zinc chloride causes a dark-gray-green coloring.

Potash and soda lye give a yellowish-whitish emulsion.

The most characteristic test to distinguish it from rape oil is its behavior towards sulphuric acid of 1.72 specific gravity.

Black mustard-seed oil is not adapted for lamp oil, and is principally used in the manufacture of soap. Commerce in it is limited, as it is only obtained as a by-product.

A volatile oil is also produced from black mustard seed after pressing out the fatty oil.

6. *Brassica chinensis*, Linn., *Chinese cabbage*, is cultivated in China, and the oil obtained by extraction.

7. *White mnstard-seed oil* (*oleum sinapis alba; Weissenföl*, G., *huile de mustarde blanche*, F.) is expressed from the seed of *Sinapis alba*, Linn. = *Brassica alba*, Boiss., or white mustard.

The seed contains 25 to 35 per cent. of oil.

Oil	29.30 per cent.	
Organic substances,	59.25 "	
protein substances therein		28.20 per cent.
with nitrogen therein		4.25 "
Ash	4.45 "	
Water	7.00 "	
	100.00 "	

The ash contains:—

Potash	10.02 per cent.
Soda	9.61 "
Magnesia	11.25 "
Lime	21.28 "
Ferric oxide	1.46 "
Chlorine	0.20 "
Sulphuric acid	5.41 "
Silicic acid	3.36 "
Phosphoric acid	37.41 "
	100.00 "

The yield of oil by pressing amounts to about 20 to 25 per cent.; the oil cake is utilized like that from black mustard-seed.

White mustard-seed oil consists of the glycerides of stearic acid, erucic or brassic acid, and of an oleic acid. It has a golden-yellow color and a peculiar, somewhat sharp, taste. Its specific gravity is 0.9145 at 59° F., and at that temperature it is 17.4 times more thickly fluid than water. It thickens at 17.6° F. and solidifies at 3.0° F. With the elaïdin test the oil solidifies to a dirty yellowish mass in about 20 hours.

Nitric acid containing some nitrous acid colors the oil very slightly; fuming nitric acid gives on the point of contact a cherry-red coloration, but without a green zone.

Concentrated sulphuric acid of 1.84 specific gravity colors the oil greenish-brown and later on darker brown. Acid of 1.72 specific gravity gives a dirty greenish-brown.

Zinc chloride produces a dirty brownish-green color.

Potash and soda lye give a yellowish emulsion and saponify the oil very quickly.

In India white mustard is cultivated for lamp oil; otherwise the oil is only obtained as a by-product. It is used for lamp and lubricating oil, but is not much employed in the manufacture of soap, at least by itself.

In California, where the mustard plant thrives and grows in such profusion that it becomes a pest to the wheat-fields, it is gathered by Chinamen, who thresh and bring the seed to the oil-mill in San Francisco, where they dispose of it at two to three cents per pound. Many who have made trial of it prefer the oil to that made of lard or the olive for cooking purposes. It is also extensively used to adulterate olive oil. The oil is sold in San Francisco at about $1.25 per gallon.

8. *Radish-seed oil* (*oleum raphani*, *Rettigöl*, G.; *huile de raifort*, F.) is obtained from the seed of *Raphanus sativus*, Linn., and the variety *Raphanus sativus chinensis oleiferus*, Linn. The seed is very rich in oil, containing between 45 and 50 per cent.

Oil	46.13 per cent.	
Organic substances	42.37 "	
albuminous substances therein		27.80 per cent.
with nitrogen therein		3.90 "
Ash	3.65 "	
Water	7.85 "	
	100.00 "	

Radish-seed oil has a greenish-reddish color, a mild taste, and is almost inodorous. It has a specific gravity of 0.9175 at 59° F., and at this temperature is 15.8 times more thickly fluid than water. It becomes thick at 14° F. and solidifies at 0.5° F. It consists of stearic, brassic, and oleic acids; when treated with potash or soda lye, it yields a yellowish soap.

Nitric acid, containing some nitrous acid, of 1.20 specific gravity, does not color the oil. Fuming nitric acid produces a red coloring with a green zone.

Sulphuric acid of 1.72 specific gravity produces a yellowish-brown coloring, and acid of 1.84 specific gravity a pure brown color lasting quite a long time.

Zinc chloride has at first no effect, but later on shows a slight grayish-green coloring.

Radish-seed oil is used as a table oil and is quite durable. It is not well adapted for lamp oil, as it deposits soot and burns away rapidly. The Chinese manufacture Chinese ink from the soot of radish oil and sesamé oil.

9. *Hedge radish seed or wild radish seed oil (Hederich oil,* G.; *huile de rhapanistre,* F.) from the seeds of *Raphanus raphanistrum,* Linn., = *R. arvense,* Wallr., a common weed frequently mistaken for wild mustard, *Sinapis arvense.* When, in 1880, the rape-seed crop of Hungary proved a failure, many experiments were made with the seeds of various plants to obtain a product similar to rape-seed oil. It was found that the seed of *raphanus raphanistrum* answered all demands in this respect. The oil was then obtained for the first time on a large scale, and at the present time, the plant, which thrives very well upon sandy soil, is largely cultivated in Hungary, and the oil expressed from the seed brought into commerce either by itself or mixed with rape-seed oil. The seed contains 30 to 35 per cent. of oil. The oil obtained by expression has a dark olive-green color, a specific gravity of 0.9135 at 59° F., thickens at 28.5° F. and solidifies at 17.5° F. It has a mild flavor with an acrid after-taste. It is rather difficult to saponify, 1 gramme of oil requiring 174 milligrammes of caustic soda, whereas 1 gramme of crude rape-seed oil requires 177 milligrammes. As the difference between these figures is very small, this behavior cannot be used for the detection of hedge radish oil in the presence of rape-seed oil. The following behavior seems, however to be characteristic for hedge radish-seed oil: About five grammes of the oil in question are partly saponified by heating with potash lye and spirit of wine, and then separated by filtration from the non-saponified oil, which is of a gold-yellow color and almost tasteless and inodorous. In the presence of a considerable quantity of hedge radish oil the pressed filtrate becomes perceptibly green on mixing with hydrochloric acid to a strong acid reaction. The behavior of crude hedge radish oil towards the most common reagents used in the examination of fat oils will be seen from the annexed table. (Five volumes of oil were mixed with one volume of the respective reagent, the mixture shaken for about three minutes, and then allowed to rest.)

Reagent.	Reaction.	Remarks.
Sulphuric acid of 1.635 specific gravity.	Dark green.	By allowing the third mixture to stand for some time, two layers are formed. With hedge-radish oil, the upper layer is grass-green, the lower the color of verdigris. Rape-seed oil shows an almost uniform olive-brown color in both layers.
Sulphuric acid of 1.430 specific gravity.	Olive green, becoming darker by standing.	
Sulphuric acid of 1.570 specific gravity.	Dark green.	
Nitric acid of 1.18 specific gravity.	Olive-green, with a yellow-brown shade.	By long standing two layers are formed; the upper yellow, the lower greenish.
Nitric acid of 1.22 specific gravity.	Olive-green, with a yellow shade.	Rape-seed oil shows a brown color shading into red.
Nitric acid of 1.33 specific gravity.	Dark-brown-green.	
Equal parts of sulphuric acid of 1.845 specific gravity and nitric acid of 1.330 specific gravity.	Dark brown.	Rape-seed oil shows a coffee-brown color.
Nitro-muriatic acid (25 parts of concentrated hydrochloric acid and 1 part of nitric acid).	Dark-yellow green.	
Nitric acid of 1.33 specific gravity and soda lye of 1.33 specific gravity.	A chocolate-colored mixture.	After long standing two layers are formed, the lower one white, which, however, in the presence of considerable rape-seed oil is yellow.
Soda lye of 1.34 specific gravity.	Yellow-green.	Rape-seed oil shows a light yellow-brown color.
Concentrated solution of potassium bichromate compounded with sulphuric acid.	Brown, shading into olive-green.	Rape-seed oil shows a light red-brown color.
Barbot's reagent—concentrated nitric acid saturated with nitric oxide.	Dark olive-green.	Rape-seed oil shows a brown color with a red tinge.
Syrup-thick solution of phosphoric acid.	Olive-green.	

Hederaceæ (*Umbellifloræ*).

Dogwood oil (*Hartriegelöl*, G.; *huile de cornouiller*, F.) is obtained from the fruits of *Cornus sanguinea*, *Linn* and *C. mascula*, a small shrub or tree indigenous to Europe. The fruits contain 17 to 20 per cent. of oil, which, as in the olive, is found in the pericarp. It is pale green, odorless, and of a not unpleasant taste. In France it is used as lamp oil and in the manufacture of soap.

Apocyneæ (*Contortæ*).

1. *Exile oil*, from *Cerbera thevetia*, Linn., a tree indigenous to the West Indies and South America, and cultivated in the East Indies. The seed contains 30 per cent. of a limpid, pale-yellow oil.

2. *Cerbera manghas*, Linn., and *Cerbera odollam*, Gaertner, which belong to the same family, yield oils used in the East Indies as lamp oil.

3. *Wrightia antidysenterica*, R. Br., yields an excellent anthelmintic oil.

Bignoniaceæ Sesameæ Labiatifloræ.

1. *Sesamé oil, gingelly oil, til or teel oil, or benné oil* (*oleum sesami; Sesamöl*, G.; *huile de sesamé*, F.) is obtained from *Sesamum orientale*, Linn., a plant much cultivated in the Levant and India. On account of its cheapness and richness in good oil, sesamé seed forms at the present time one of the most important raw materials for obtaining oil, especially in France and England, and recently also in Germany and Austria. The brownish to black Levantine seed contains 50 to 60 per cent. of oil better adapted for table purposes than that from Indian seed, which contains only 47 to 52 per cent.

	Brown Levantine seed.		Yellowish Indian seed.	
Oil	55.63 p. c.		50.84 p. c.	
Organic substances	30.95 “		35.25 “	
protein substances therein		21.42 p. c.		22.30 p. c.
with nitrogen “		3.39 “		3.56 “
Ash	7.52 “		6.85 “	
Water	3.90 “		7.06 “	
	100.00 “		100.00 “	

The seed is generally pressed three times, twice cold and the third time warm.

The yield of oil varies between 45 and 50 per cent. and that of oil cake between 50 and 55 per cent.

1st pressure extra-fine table oil	25 to 30	per cent.
2d " " "	10 to 10	"
3d " ordinary oil	10 to 10	"
	45 to 50	"

In Calcutta, where the seed is pressed only twice, the average yield from the

1st pressure is fine oil	36	per cent.
2d " ordinary oil.	11	"
	47	"

The oil cake has the following composition:

Water	8.25	per cent.	
Fat	7.63	"	
Substances free from nitrogen	40.90	"	
Protein substances	32.82	"	
nitrogen therein			5.25 per cent.
Ash	10.40	"	
	100.00	"	

The separate constituents of the ash of the cake are distributed as follows;

Potash	20.82	per cent.
Soda	5.63	"
Magnesia	14.47	"
Lime	15.13	"
Ferric oxide	2.00	"
Chlorine	1.74	"
Sulphuric acid	3.20	"
Silica	6.82	"
PHOSPHORIC ACID	30.19	"
	100.00	"

The first cold-drawn oil is the best, and as a table oil is esteemed equal to the best olive oil, and even preferred to it on account of its slightly piquant flavor. The oils pressed in Europe are superior in quality to all others.

Sesamé oil obtained by extraction, as well as that by the third pressure, is used in France only in the manufacture of soap.

Sesamé oil is of a beautiful golden-yellow color, almost inodorous, and has a characteristically pure and mild flavor. At 59° F. it is sixteen times more thickly-fluid than water. Its specific gravity is 0.9188 at 68° F., 0.9235 at 59° F., and 0.9272 at 50° F. The oil remains clear at 39.0° F., but becomes gradually thicker below that temperature, and solidifies to a uniform yellowish-white mass at 23° F.

The elementary composition of the oil is as follows:—

Carbon	75.22	per cent.
Hydrogen	11.13	"
Oxygen	13.65	"
	100.00	"

It consists of the glycerides of oleic acid, besides of stearic, palmitic, and myristic acids, and a somewhat resinous substance not yet thoroughly known, which can be obtained by frequent shaking and treatment with glacial acetic acid.

Nitric acid of 1.20 specific gravity colors the oil yellowish-red, the color, according to the concentration of the acid, passing more and more into yellow-red. The same effect is produced by shaking with a mixture of equal parts of sulphuric and nitric acids and water, though at first a transitory green color is observed.

With the *elaïdin test*, and also by treatment with nitric acid and copper or starch, the oil in a short time becomes red, but later on the mixture changes to a dirty reddish-brown, becomes opaque, and remains only curdy even after twenty-four hours.

Sulphuric acid of 1.72 specific gravity colors the oil first brown and, on stirring, green; acid of 1.84 specific gravity, first dark-brown and, on stirring, dirty greenish-brown.

Zinc chloride does not color the oil.

Glacial acetic acid shaken with an equal volume of sesamé oil, and the mixture heated to 224.6° F. gives a clear solution.

Of *iodine* up to 39 per cent. is dissolved by sesamé oil.

Potash and soda lye and *ammonia* give a whitish emulsion, saponification taking place quite rapidly on heating.

Solution of *nitrate of silver* is not reduced.

The only profitable adulteration of sesamé oil would be with peanut oil, the specific gravity of which, 0.918, is considerably less than that of sesamé oil, and besides the sulphuric acid test is decisive.

Saponification number of the oil	192–193
Iodine number of the oil	103–105
Iodine number of the fatty acids	110–112
Fusing point of the fatty acids	95°–96.8° F.
Solidifying point of the fatty acids	89°–89.6° F.

Sesamé oil is used for edible and culinary purposes, as illuminating oil, lubricating oil, for perfumery purposes, and in the manufacture of soap; it is also employed for adulterating olive oil, which see.

The sesamé seed trade from the East Indian ports and the Levant is of considerable importance; the Java seed is most highly valued, it yielding oil of the palest color and finest flavor. The greater portion of the oil is expressed in the Mediterranean markets, especially in Marseilles and Trieste. France imports annually about 77,000 to 88,000 tons of sesamé seed.

The oil is shipped in wooden barrels holding about 1320 to 1540 lbs. (600 to 700 kilogrammes).

2. *Paulownia imperialis*, Sieb. and Succ., a beautiful tree of Japan, yields an oil much used by the Japanese known as "*huiledetoï*," or "*abura toi*," which, as regards its properties, is inclined towards the drying oils.

Oleaceæ (*Ligustrinæ*).

1. *Olive oil, sweet oil or salad oil* (*oleum olivarum; Olivenöl, Baumöl or Provencer Oel*, G.; *huile d'olive or huile de Provence*, F.) is expressed from the fruit of *olea europaea*, Linn., or the common olive tree.

In Southern Europe there are two principal species of olive trees:

a. *Olea europæa sylvestris*, the oleaster (wild olive), having a kind of thorn, very short leaves and producing only a few small berries.

b. *Olea europæa sativa*, without thorns, lanceolate leaves and large fruits. Seedlings of the sativa sometimes deteriorate so as not to be distinguished from the oleaster. The latter species only, yields oil. There are numerous varieties—from forty to one hundred—which differ not only as regards habitat, but also in the size and shape of the flowers and the size of the fruit.

M. Barbe, sr., in his "Etudes sur les Oliviers" describes four varieties as follows:

The *Blanquetier*, which grows large, branchy, with light green foliage; the fruit is small, the pulp has at first a bitter taste, then a mellow after-taste; the oil is abundant; it blossoms freely, but too often disappoints the hopes for fruit.

The *Blavier*, which has a very rustic appearance, is very hardy; its fruit is oblong and comparatively large; the pulp is coarse, the oil deeply colored; the fruit is sensitive to cold.

The *Arabanier* or *Araban* is less rustic and less lofty than the last; its foliage is poor, the fruit round; the oil is of ordinary quality, better when made from fruit not quite ripe. This tree is hardier than either the Blavier or the Blanquetier, and resists better the effects of wind and frost.

The *Cailletier*, well known and popular for years past, grows tall; its branches hang low, the leaves are glossy dark green on the upper surface, nearly white underneath; the bark is rough and of a gray hue; the tree appears less green than the other varieties because of the disposition of the branches; the fruit, in clusters at the ends of the branches, is of good size, convex on one side, concave on the other; yields oil which is of superior quality in all points. This tree, also known by the characteristic name of *Pendoline*, thrives best in dry lands; at its best, its fruit sells for a third more than others for mixing with poorer qualities. It is a robust tree and can be severely pruned. Its greatest enemy is the *Dacus oleæ* or *Keïron*. Cattle, too, if pastured in the grove, must be kept from its low-hanging branches. Other good varieties for oil are the *Nirvana*, also called *Naustrales* and *Brocienne;* the *Auriola*, also called *Pignola;* the *Nicoise*, the *Blanche*, the *Roberon*, the *Negrette*, the *Sager*, the *Caillan*, etc.

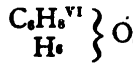
For preserving the *Verdale*, a large oval fruit, the *Amenlean*, the *Lucques*, a small variety with sharp pointed stone. The *Poncinere*, grown everywhere in the "Alpes Maritimes," the *Caliiache*, too, and the *Picholine* are well liked.

In the department of "Alpes Maritimes," the olive covers about 70,000 acres; it yields a revenue of $2,000,000, and is the only income of many families.

Olives are harvested from September to December and picked by hand, or the farmers spread sheets under the trees and knock the fruit down with poles.

1000 grammes of olives contain:

	Fresh.	Dried.
Flesh with skin	714.29 grammes	572.62 grammes.
Stone	232.25 "	380.15 "
Seed	53.46 "	47.23 "
	1000.00 grammes.	1000.00 grammes.

Unripe olives contain mannite  $\left.\begin{matrix}C_6H_8^{VI}\\H_6\end{matrix}\right\}O_6$ a hexatomic alcohol which during the ripening of the fruit is converted into fat oil, because no mannite is found in the ripe fruit.

The rind (exocarp), flesh (mesocarp), stone (endocarp), and seed of the olive contain each a special oil with more or less solid fatty acids; the oil from the flesh contains, for instance, considerable less palmitin and remains fluid at quite a low temperature.

The amount of oil in olives varies between 30 and 50 per cent., though it sometimes occurs that the flesh contains as much as 70 per cent. of oil besides 25 to 30 per cent. of water and 5 to 10 per cent. of organic substance.

The olives, etc., contain:—

	Flesh.	Stone.	Seed.
Oil	56.4 p. c.	5.75 p. c.	12.26 p. c.
Organic substance	16.70 "	85.89 "	79.38 "
nitrogen therein	1.10 p. c.	2.50 p. c.	2.16 p. c.
Ash	2.68 "	4.16 "	2.16 "
Water	24.22 "	4.20 "	6.20 "
	100.00 p. c.	100.00 p. c.	100.10 p. c.

The ash contains:

	Flesh.	Stone.	Seed.
Potash	80.90 per cent.	58.80 per cent.	30.25 per cent.
Soda	7.53 "	6.60 "	1.96 "
Magnesia	0.18 "	0.36 "	1.15 "
Lime	7.46 "	7.45 "	30.39 "
Ferric oxide	0.72 "	0.81 "	0.11 "
Chlorine	0.18 "	4.72 "	0.11 "
Sulphuric acid	1.05 "	3.27 "	2.43 "
Silica	0.65 "	1.25 "	5.36 "
PHOSPHORIC ACID	1.33 "	15.74 "	28.24 "
	100.00 per cent.	100.00 per cent.	100.00 per cent.

For the preparation of the finest oil, known as "virgin oil," only the flesh of olives picked by hand is used. The olives are spread separately upon a linen cloth for four to five days and then carefully peeled piece by piece, so that not the smallest piece of rind remains. Later on the flesh is carefully separated from the stone and reduced to a pulp in suitable mortars. The pulp is packed in strong linen and the oil expressed by twisting the linen together. The residue, which still contains much oil, is pressed for a second quality of oil. The virgin oil is allowed to settle in a cold place from which the air is excluded as much as possible, and after about a month is filtered.

For the preparation of other oils the olives are reduced to a pulp without previous peeling and stoning, and the pulp pressed.

The method of preparing olive oil varies in different countries, but all agree in the principle of fabrication that for the best quality of oil the olives are only subjected to a slight cold pressure, for the second or ordinary quality to a stronger cold pressure, and for the third quality to warm pressure, with an addition of warm water to the pulp. A fourth quality of oil is obtained by boiling the residue with water.

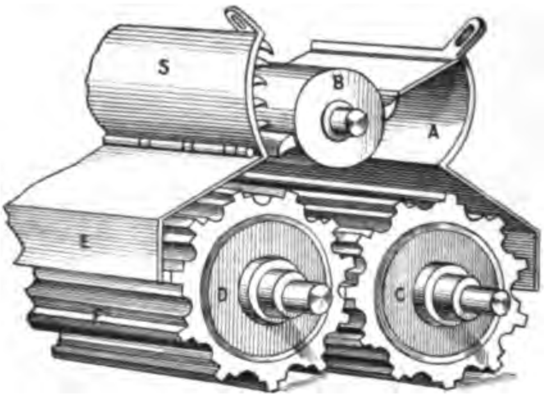
In Southern France and Northern Italy the process of manufacture is as follows: Before the olives enter the mills they are carefully spread over the floor of the well-ventilated store-room, where they are allowed to dry for three days if the wind is from the south, and four or five days if from the north. The olive seems to lose no oil until the humidity is taken out, but water, hot or cold, or still better, oil, must be added to olives too dry to cause their oil to flow.

The first stage in the operation consists in crushing the olives. The mill in use to-day for this purpose, differs little from those used for centuries, it consisting, as a rule, of a single horizontal stone running upon a bottom-stone. Sometimes there are two vertical stones set at such a distance from the bottom-stone that the stones of the olives are not crushed. When the olives have been reduced to an oily paste, the latter is shoveled out and packed into flattish-round woven grass-bags which are taken to the presses. The latter are simply rough heavy frames fitted with large screw presses worked by hand. The bags are piled up in single piles, like so many cheeses, on the wide oak slab forming the bottom of the frame, and the presses are screwed down upon them with a hand-bar. The first oil running off, if a fine quality of olives is used and due care has been observed, is of good quality and is brought into commerce as "salad oil" and frequently even as "virgin oil," though the latter is a thing which cannot be found by the ordinary consumer.

Semler in his work "Tropische Agricultur," gives directions for the construction of a mill for crushing olives. The upper roll *B*, Fig. 227, comminutes the olives to coarse pieces while the lower rolls C and D crush the cells. Since the rolls can be set at any desired distance from each other, the olives may be entirely crushed or the stones left whole.

After the first pressure the residue, called in Italy "*sanza*," or "*nocciulo*," still contains a considerable quantity of oil, which, however, is so enveloped by the other constituents of the fruit that the presses ordinarily used cannot force it out. To obtain a further portion of the oil the nearly dry press-cakes are ground, soaked with water and again subjected to cold pressure. For the reception of the oil mixed with water two capacious vessels are provided, one of which is being filled, while in the other the oil separates from the water; the oil rising to the surface of the water is skimmed off with large tin skimmers.

FIG. 227.



MILL FOR CRUSHING OLIVES.

The residue from the second pressure also called "*buccia*" is treated in the same manner with hot water.

C. Cooper, of San Francisco, gives the following method of the manufacture of olive oil in California: The fruit should be gathered as soon as it turns purple, and before fully ripe, as the the oil will be lighter in color and more fragrant, but somewhat less in quantity. The more economical plan of gathering is to pick from the trees by hand and by the aid of intelligent contrivances. An active man can pick four hundred pounds per day. The leaves and imperfect berries are separated by passing the whole through a winnowing mill. The process leaves the fruit in the best possible condition preparatory to manufacturing the oil.

The berries are dried before crushing, as it is necessary to evaporate a portion of the water. If, however, they are left out on the trees until shriveled, which is proof that necessary evaporation has already taken place, no drying is needed after picking. By artificial heat, ranging from 110° to 130° F., the drying can be done in less than forty-eight hours. The crushing and pressing should follow without delay; that is, the fruit taken from the drier in the morning should be crushed and pressed the same day. To make perfect oil requires a perfect system in the whole management. The capacity of the press, the crusher, the drier, and the number of pickers, should correspond, or be about equal. All fruit picked during the day should be in at night, cleaned the following morning, and go into the drier immediately after the previous day's drying is taken out. The heat or temperature of the drier ought to be so graded as to complete the work in forty-eight hours, and it is better that it should be below 130° F. rather than above.

The almost universal method of crushing the olives is by a heavy stone similar to a millstone, which is rolled around on the edge in a deep circular groove or trough, and by its weight does the crushing. A beam passing through the eye of the stone and working on a journal in the centre of the circle, with a horse attached to the outer end of the beam, is the simplest way tó do the work. The crushed olives are put in the press in cheeses about three feet square and three inches thick, with wooden slats between each cheese. Ten or more cheeses can be put in at each pressing. Coarse linen cloths are used to contain the olives.

The fluid that is expressed is put in large tanks and left for sixty to ninety days, when the oil will separate and, being lighter, will rise to the top, where it can be drawn off. The pomace after the first pressing is recrushed, and by pouring hot water over it a second quality of oil is expressed. The refuse can then be used either for fuel, for feed for pigs, or for making still a third quality of oil. If for the latter it is thrown in vats, boiling water poured over it and left to ferment, when the oil still remaining will be liberated and rise to the top.

The most common method of filtering or clarifying the oil is to have a series of five or six boxes, one above the other, each with cotton batting in the bottom. The oil passing the sixth will be beautifully clear and ready for market. The oil should be kept in an ordinarily cool place, not exposed to sunlight or heat, neither should it be handled more than absolutely necessary in the filtering and bottling.

The air-dry cake contains:

	I.		II.	
Oil	10.50 p. c.		11.82 p. c.	
Organic substance	76.58 "		73.53 "	
protein substances therein...		8.60 p. c.		9.82 p. c.
Ash	4.12 "		3.90 "	
Water	8.80 "		10.75 "	
	100.00 "		100.00 "	

The composition of the ash of No. II. is as follows:

Potash	27.82 per cent.
Soda	6.50 "
Magnesia	1.38 "
Lime	21.62 "
Ferric oxide	7.50 "
Chlorine	0.80 "
Sulphuric acid	4.50 "
Silica	20.85 "
PHOSPHORIC ACID	9.03 "
	100.00 "

The oil retained by the residue—"sanza and buccia"—is extracted with carbon disulphide, the first establishment for this purpose having been started, in the sixties, in Puglia in the region of Bari, Italy, which abounds with olive trees. At present there are 20 such establishments scattered throughout the provinces Bari, Lecce and Calabria, Italy, of which the largest works up 750 quintals* of sanza in 24 hours, five each 300 quintals and the rest 100 to 150 quintals each. The annual production of oil amounts to more than 3,300 tons.

In fall, during the olive harvest, the fresh sanza is brought to the factories, where, in order to keep it for some time, it is piled up in large store-houses and pressed to a solid mass by constant rolling with heavy stone or iron cylinders, the latter being filled with sand. The more solidly the sanza is pressed together, the longer can it be kept, the danger of heating or spontaneous combustion being thereby reduced to a minimum.

Work in the factories commences generally about the middle of November, and continues eight to ten months, according to the quantity of sanza on hand.

The absorbing capacity of carbon disulphide being considerably greater if the material subjected to its action is perfectly dry, the sanza is dried by spreading it out, about six inches deep, in the sun, and turning it from time to time with a shovel. Some factories are provided with a mechanical drier to allow of the operation being carried on in rainy weather. Such apparatus consists of an Archimedean screw which forces the sanza through conduits heated by steam.

For extracting the oil from the dry sanza the apparatus, shown in section in Fig. 228, and in upper view in Fig. 229, is used.

The extracting vessel has a capacity of 742 cubic feet and holds 27,500 lbs. of sanza. In the Daninas factory in Pisa, two such apparatuses are in use, and both together yield at each operation, lasting 30 hours, on an average from 5,500 to 6,000 lbs. of oil. The principal constituents of the apparatus are: A cemented brick cistern, *A*, lined with lead for the reception of the carbon disulphide; it is about 22 feet long, 6½

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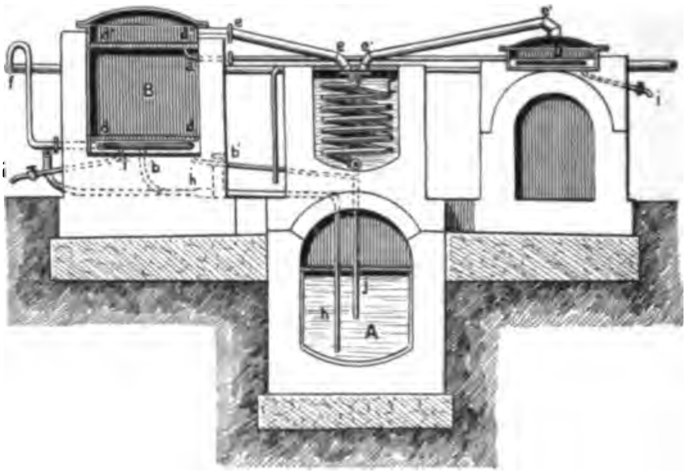
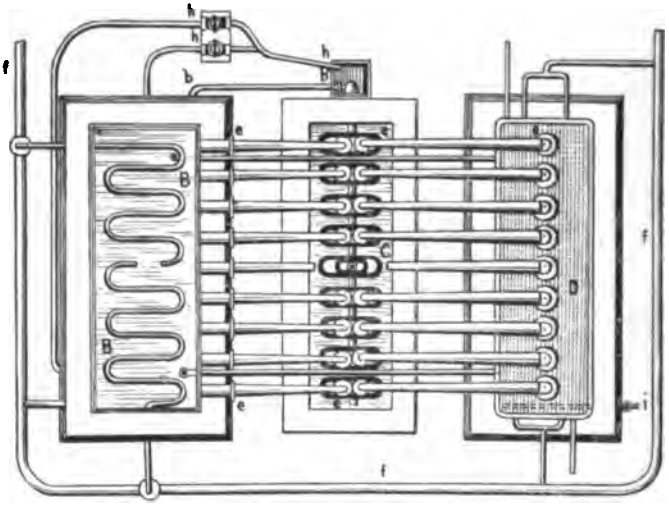
* 1 quintal = 100 Kilogrammes = 220 lbs.

FIG. 228.



SECTION.

FIG. 229.



UPPER VIEW.

APPARATUS FOR EXTRACTING SANZA.

feet wide and 6 feet deep; an extracting vessel *B* of 21,000 quarts capacity, a condenser *C* and the distilling apparatus *D*, which is about 11½ feet long, 5½ feet wide, and, measured to the lower edge of the lid, 16 inches deep; when half full it holds about 1,800 quarts of fluid.

Work with this apparatus is carried on as follows: The cover of the extracting vessel being opened, the dry sanza is introduced and rests upon the perforated bottom *dd*, 5¾ inches above the actual bottom. When the extractor is full, another perforated bottom *d' d'* is placed on top of the sanza, and the cover hermetically closed. The pumps *h h* are then set to work, and the suction pipe *h'* draws carbon disulphide from the cistern *A*. The carbon disulphide is conveyed below the perforated bottom *d d* into the extractor *B*, and in ascending gradually penetrates the mass contained therein. The work of the pumps is so regulated that *B* is filled in about eight hours. Extraction commences the moment the carbon disulphide comes in contact with the sanza. The carbon disulphide charged with oil becomes thereby specifically lighter, and is displaced by fresh carbon disulphide flowing in from below. When the extractor is filled, the upper portions of the carbon disulphide are nearly saturated with oil. The oil solution is then forced by the pumps through the pipe *a*, entering immediately above the perforated bottom *d'*, into the distilling apparatus *D*. Upon the bottom of the latter lies the steam-coil *d*, by means of which the carbon disulphide is vaporized in proportion as the oil solution flows in. The vapors escape through nine pipes *e' e'* into the large coil of the condenser *C*, where they are condensed; the condensed carbon disulphide flowing through the pipe *f* back into the cistern *A*. The pumps *h h* in the meanwhile continue at work, and constantly force fresh carbon disulphide from below into the extractor until the solution running off at *a* is entirely colorless, which can be observed by means of a glass tube inserted in the end of *a*. The sanza is as a rule sufficiently exhausted four hours after the oil solution begins to run off. By opening the cock on the pipe *b b'* the entire quantity of carbon disulphide in the extractor *B* is then allowed to run back into the cistern *A*. The cock on the pipe *b b'* is then closed, and by opening the cock on the pipe *f* direct steam is admitted below the perforated bottom *d d*, which penetrates the sanza in the extractor *B*, and vaporizes the remainder of carbon disulphide. The vapors escape through nine pipes *e* into the principal coil in *C*, where they are condensed and consisting now partially of water and partially of carban disulphide, run through *f* into *A*, where, by reason of their different specific gravities, they are separated. When the exhausted sanza in the extractor *B* has been sufficiently steamed, the condensed water in *B* is discharged through the pipe *i*. The cover is then removed, the exhausted sanza thrown out, and the operation commenced anew. The oil remains in the distilling vessel *D*. To remove the last traces of carbon disulphide tenaciously retained by the oil, and to regain them, direct steam is blown into the oil. The oil thus obtained is chiefly used in the manufacture of fine qualities of soap.

In more factories two extracting apparatuses are connected with each other, and the solution of fat from the first extractor is allowed to run directly into the distilling apparatus only so long as it is rich in fat. When the carbon disulphide in the first extractor no longer absorbs much fat it is forced into the second extractor, in which it ascends and, impregnated with oil, flows into the distilling apparatus. In the meanwhile the contents of the first extractor are exhausted when the carbon disulphide is discharged, and the operation continued as above described. The first extractor is then refilled with fresh sanza, the weak oil solution forced from the second extractor into the first, etc., so that the oil solution is systematically enriched before being subjected to distillation. For distilling the carbon disulphide charged with oil—which is called *miscello*—shallow stills are no longer used, but a cylindrical apparatus, and the carbon disulphide coming from the condenser is collected in a reservoir suspended in a cistern filled with water from which it passes into the extractor.

The oil extracted with carbon disulphide is as a rule of quite a dark brown color, partially due to coloring matter dissolved by the carbon disulphide, and partially to small quantities of iron. By boiling with sulphuric acid by means of direct steam the oil, according to Giseke, acquires a much paler color, becomes perfectly clear, and finally greenish, but is always considerably darker in color than oil obtained by pressing.

Olive oil obtained by extraction with carbon disulphide differs from expressed oil in being soluble in absolute alcohol, as well as in alcohol of 0.830 specific gravity.

Olive oils are divided into two principal varieties.

I. *Salad oils* (*huile d'olive commestibles*) which are obtained only by cold pressing:

a. Superfine table oil, virgin oil (*huile vierge, huile de Provence*) expressed from the choicest fruit. It has a greenish-yellow, pale golden-yellow, or pale yellow color, and a very mild and agreeable flavor. It is produced chiefly in Provence, especially at Aix and Grasse, France, further in Genoa, Tuscany and the Neapolitan province Bari, Italy. The annual output amounts to about 100,000 quintals. The best oil is again divided into six qualities, the best being designated *AA* and *A*, and the others 1 to 4.

b. Ordinary table oils obtained from the entire crushed olives of various degrees of ripeness. They are a pale yellow.

The principal varieties of table oil known in commerce are distinguished by the place of production. "*Provence oil*" is the most highly esteemed; "*Florence oil*," "*Lucca oil*," and "*Genoa oil*" come next; while "*Sicily oil*" and "*Spanish oil*" are of inferior quality, the last being the worst.

II. *Huile d'olive à fabrique* (*fabricated oils*).—Under this name are classed oils not fit for table use and prepared in various ways. They are all turbid, have a disagreeable odor and taste, and require several months for clarification. According to the manner of preparation or technical use they are divided into:—

a. Illuminating oils (*huiles lampantes, huiles à bruler*) also called when entirely clarified and transparent *huiles brillantes.* They are obtained by hot pressure, and transported in leathern pipes to Gallipoli, in the Province of Lecce, Italy, where they are emptied into cisterns cut out of the rock and allowed to clarify.

b. Gorgon (*huiles de recense or de ressence*). This name is given to the oil obtained from the last pressure, with the assistance of warm water. It has generally a green color, disagreeable odor, and is very thickly fluid. By standing the oil separates into two layers, the upper one of which is clear and is used for machine oil and for dressing wool, while the lower turbid layer is employed in the manufacture of soap.

c. Oils of the infernal regions (*huiles d'enfer*). Though the press residues by treatment with hot water yield a certain quantity of oil, the tissues of the olives are not completely exhausted. By collecting the residues in deep cisterns half full of water, called in France "*enfer*," a very inferior quality of oil collects on the surface and is skimmed off. On account of its very disagreeable odor it is called *huile d'enfer.* It is used in the manufacture of soap.

To the last variety belongs also the fermented olive oil (*huile tournante*) considerable quantities of which are used in Turkey red dyeing. This oil is prepared from strongly fermented or rotten olives or press-residues in the same state. It is turbid from admixed mucus and parenchyma, very acid from free oleic acid, and generally of a green color. When shaken with potash or soda solution it yields an emulsion which keeps a considerable time without separating. This emulsion is used as a white bath or oil-mordant in Turkey red dyeing. It does not possess the properties of a soap solution, but in conjunction with heat, light and air cleanses the fibres of the tissue and renders them flexible in a manner not yet thoroughly understood. The tissues do not become saturated with fat, otherwise the fibre would be incapable of taking the alumina mordant subsequently used, and the dye.

The Turkey red oil is frequently imitated by mixing 100 parts of rape-seed oil or olive oil with 10 to 20 parts of oleic acid.

For purifying and refining olive oil of inferior quality, Seidel uses a vat with conical bottom, furnished with a steam-coil. About 3 to 4 inches above the bottom is a cock for the discharge of the impurities, and about 3 to 4 inches above the level of this cock another one for the discharge of the oil. The vat holds about 20 cwt. of oil and rests upon a stone foundation. Alongside of it, arranged in the form of steps, stand 5 to 6 clarifying vessels supported by a strong wooden frame. These clarifying tanks, which may also be constructed of tin-plate, are cylindrical, provided about ¾ to 1 inch above the actual bottom with a perforated sieve-like bottom, and above the latter with a helmet. Upon the perforated bottom is placed a layer of cotton or better of glass-wool, the latter deserving the preference, because it can be used for years. For every 50 lbs. of oil to be purified 5 to 7.5 lbs. of water are added. The oil is next boiled by means of steam for 2 or 3 hours, and then allowed to repose for 14 hours, when the water will have settled at the bottom. The cock is then opened and the oil discharged into the first clarifying tank; when this is full, the contents are discharged into the second clarifying tank, from the latter into the third, and so on. From the last clarifying tank the oil comes clear and bright.

The elementary composition of olive oil is:—

Carbon	77.20	per cent.
Hydrogen	11.30	"
Oxygen	11.50	"
	100.00	"

It consists principally of triolein, about 72 per cent., palmitin and arachin, $\left.\begin{matrix}(C_{20}H_{39}O)_3\\ C_3H_5\end{matrix}\right\} O_3$, the glyceride of arachinic acid, and very little stearin. It also contains cholesterin $C_{26}H_{44}O$, which up to the year 1862 was only known to exist in the animal body, where it forms an important constituent of the gall, the blood-corpuscles, and the nerve substance.

The green color of olive oils is due to chlorophyl.

Pure olive oil is almost inodorous and has a peculiarly mild taste. It soon becomes rancid. Its specific gravity is:—

0.9208 at	50° F.	0.9143 at	68° F.
0.9192 at	53.5	0.9109 at	77
0.9177 at	59	0.8932 at	122
0.9159 at	63.5	0.8625 at	201

The oil becomes turbid at 39° to 41° F., and separates white crystalline grains of palmitin. At 35.5° F. it assumes the consistency of butter, and completely solidifies below 32° F.

The low grades of hot-pressed oil are richer in palmitin, become sooner turbid, and solidify at 41° to 43° F., some even at 50° F. Their specific gravity varies from 0.916 to 0.920 at 59° F., being sometimes even 0.925.

When heated these oils have the peculiarity of becoming paler at 248° F., and almost colorless at 428° F., but on cooling they regain their original color. Their apparent boiling point is at 599° F., but rises with constant decomposition of the oil.

The oil is very sparingly soluble in alcohol, while 5 parts of ether dissolve 3 parts of oil, and the same quantity of acetone only 1 part. With chloroform, benzol, and carbon disulphide it is miscible in all proportions.

Nitric acid of 1.20 specific gravity colors the bright salad oils pale greenish to green, and the poorer qualities dark grass green, which in the course of a few hours passes into a brownish color.

By adding to the mixture of oil and nitric acid, starch or copper filings for the development of nitrous acid, the salad oils solidify in one to two hours into a white granular mass, and the other oils into a yellowish-white to yellowish-brown mass.

Fuming nitric acid forms on the point of contact a quite wide, pale blue-green zone. Three parts of the acid diluted with 2 parts of water solidify 15 parts of oil in one to two hours.

Oil exposed to the sunlight for two to three months is acid, and, on treating with nitrous acid, does not yield elaïdin.

Sulphuric acid of 1.50 to 1.60 specific gravity gives pale greenish colorations, which, later on, pass into brownish; acid of 1.84 specific gravity, green colorations, which soon pass, first into gray brown and then into dirty brown.

A mixture of equal parts of *sulphuric* and *nitric acid* produces, in salad oils, a very slight green color, and in the other oils a green color which becomes paler after standing. The mixture, according to the oil, separates into a turbid layer of oil and a clear layer of acid mixture of a slightly yellow-brownish color.

If *glacial acetic acid* be heated with equal parts of olive oil and the mixture heated, the latter with green olive oil becomes clear at above 185° F.; with yellow olive oil, however, only above 230° F.

Solution of nitrate of silver has no effect upon olive oils.

Of *iodine* up to 44 per cent. is dissolved by olive oil.

Zinc chloride gives, with salad oils, a very slight rose color; with other oils a greenish color.

Five parts of *potash lye* or *ammonia* shaken with one part of oil give nearly snow-white liniments.

Olive oils, on account of their high price, are very much subject to adulteration.

For a general test of salad oils, adulterations can, with some experience, be readily detected by taste and odor, especially an addition of peanut oil, which imparts a peculiar bean-like taste. Walnut oil and poppy-seed oil also give to olive oil a peculiar taste, readily recognized. The presence of the last-mentioned oil may also be established in a rather primitive manner as follows:

Pure olive oil when vigorously shaken becomes covered with small bubbles which rapidly disappear; in the presence of poppy-seed oil the bubbles are larger, coherent and remain for a long time.

Serra Carpi has proposed a peculiar method of testing olive oil for an admixture of foreign oils, the practical utilization of which is, however, rather difficult. A sample of the oil to be tested is laid for three hours in a freezing mixture (ice and salt) of -4° F. The solidity of the frozen oil is then tested with a cylindrical iron rod two millimeters in diameter and one centimeter long and provided with a conical point. This iron rod is loaded with weights until it sinks entirely into the frozen mass, the result being expressed in grammes. With the best qualities of olive oil this pressure amounts 1700 grammes, with other qualities to less, but always to over 1000 grammes; with cotton seed oil it amounts only to 25 grammes. If olive oil be added to the latter, the hardness increases the more rapidly and to a greater extent, the more closely the mixture approaches pure olive oil. For mixtures of these two oils Carpi has constructed a scale of hardness by which, when the hardness of the variety of olive oil used in the mixture is known, a conclusion may be drawn from the determined hardness as to the quantity of cotton-seed oil added.

The electrical conductivity of olive oil being much lower than that of all other vegetable oils—according to Rousseau 675 times lower than that of the worst conducting oil—by testing it an accurate conclusion may be drawn as to the purity of the oil. Palmieri has constructed for this purpose a special apparatus, which he calls the "*diagometer*." It consists of a dry galvanic pile, one conducting wire of which dips into a small metallic dish containing the oil, and communicates with the pivot of a magnetic needle, while the other conducting wire is in contact with the earth. The electrical conductivity of the oil is calculated from the arc the needle traverses in a circle on a glass bell covering it, and determined by the time the needle requires for attaining its greatest deviation. The smallest addition of other olls increases the electrical conductivity of olive oil, it being, for instance, increased fourfold by the addition of 2 drops of poppy seed oil to 5 grammes of olive oil. The apparatus, however, is expensive and not easy of manipulation; furthermore, besides adulterations, olive oil is subject to alterations which render the results of the test unreliable.

For the same reason, that olive oil is subject to alterations, no reliable results are obtained by *spectroscopic examinations.* It may only be mentioned that olive oil shows in blue and violet a deep shade with a scarcely perceptible line into green, and possesses a very slight ribbon in orange and a very strong dark ribbon in red. Refined cotton seed oil shows in blue and violet no difference from olive oil, while the spectrum in green and red is continuous and the last two ribbons are wanting.

The absorption-ribbons do not belong to olive oil, but are characteristic of the chlorophyl spectrum, they being not produced by bleached olive oil.

Although the elaïdin and nitric acid tests furnish, according to the extensive investigations of E. Dieterich, excellent guiding points for judging olive oil, reliable results can only be obtained by exact quantitative examinations (iodine number, saponification number, etc.), all other qualitative methods of testing yielding more or less uncertain results. The iodine number is an excellent means for recognizing pure olive oil, all oils used for adulteration showing higher iodine numbers.

Saponification number of the oil:	table oil	190–193
" " "	technical oil	186–188
Iodine number of the oil:	table oil	82– 83
" "	technical oil	82
Fusing point of the fatty acids		80°–82.4° F.
Solidifying point of the fatty acids		71°–71.6° F.

Nitric acid colors olive oil only greenish; if peanut oil be present it becomes reddish, in the presence of sesamé oil, orange, and in that of cotton-seed oil, brownish.

The presence of sesamé oil in olive oil, and in all other oils, is indicated by the following method; Shake equal parts of hydrochloric acid and a small piece of cane sugar with the oil. If, after standing, a red color is developed, sesamé oil is present, the quantity being approximately estimated by the intensity of the color. Levantine sesamé oil shows the reaction somewhat stronger than the Indian variety.

A mixture of *nitric and sulphuric acids* has, as stated above, very little effect upon olive oil, but in the presence of foreign oils it becomes colored at once, an adulteration with sesamé oil showing a transitory bluish-green coloring, with peanut oil a reddish-brown, and with sunflower oil a reddish-yellow, after some time.

The presence of *cotton-seed* oil is recognized by a purple color on treating with *snlphuric acid.*

In Portugal olive oil is extensively adulterated with oil from *Jatropha curcas*—purgir nut oil—p. 439. Such adulteration, up to 10 per cent. may be detected if, by treating the oil in question with copper and nitric acid, the layer of oil after some time acquires an intense red-brown coloration. The presence of *rape oils*, which are used only for the adulteration of inferior qualities of olive oil, is detected by the silver test or by boiling with lead plaster, p. 479, and by the black coloration.

In the Paris Municipal Laboratory the "*Aréomètre thermique*" constructed by Langlet is used for the examination of olive oil. The instrument is so constructed that with pure olive oil the statements of the spindle and of the thermometer in the interior of the instrument agree at every temperature. The statements, however, differ one from another if the oil is adulterated. By these means small additions of sesamé, cotton seed, poppy seed or hemp seed oils may be recognized; but on the other hand, considerable adulterations with peanut oil and rape seed oil may be overlooked. With pure olive oil the error of the instrument, *i. e.*, the difference between the statements of the thermometer and of the spindle, is at the utmost 1 degree, but is generally below 0.5 degree.

Some examples of the statements with pure oil and mixtures are as follows:

	Thermometer.	Spindle.
Peanut oil	18.9° C.	11.0 degrees.
Cottonseed oil	18.9 "	10.5 "
75 parts olive oil, 25 cottonseed oil	18.1 "	16.1 "
67 " " 33 " "	18.6 "	15.8 "
75 " " 25 sesamé oil	18.3 "	16.5 "
67 " " 33 "	18.6 "	16.1 "
75 " " 25 colza oil	18.3 "	18.5 "
75 " " 25 peanut oil	18.1 "	17.2 "
67 " " 33 "	18.7 "	17.5 "
52 " " 48 "	18.7 "	17.4 "

Under the name of *Malaga oil*, oils sometimes colored green with verdigris occur in commerce. The content of copper may, according to Cailletet, be detected by dissolving 0.1 gramme pyrogallic acid in 5 cubic centimetres ether, and shaking the solution with 10 cubic centimetres of oil. The mixture acquires a brown color and separates pyrogallate of copper. Oils free from copper neither turn brown nor become turbid.

In testing olive oil rancidity and the degree of acid have also to be taken into consideration, and for the latter purpose Burstyn's apparatus remains to be mentioned. The instrument indicates in degrees the content of free fatty acid in an alcoholic fatty acid solution, To obtain this fatty acid solution, vigorously shake in a tall glass cylinder a hundred cubic centimetres each of 88 to 90 per cent. alcohol and oil, allow the mixture to repose for some time until the alcohol has entirely separated from the oil; the alcohol has then taken up the oleic acid as well as the other fatty acids. Now determine with the instrument, which is actually an areometer graduated into 50 degrees, first the gravity of the pure alcohol and then the gravity of the alcohol containing the fatty acids. From the difference in the specific gravities the content of acid can then be determined with the assistance of a table accompanying the instrument. One Burstyn degree of oleic acid = 1 cubic centimetre of normal hydrychloric or normal oxalic acid, and consequently corresponds also to one cubic centimeter of normal alkali solution, and the latter again to 0.28 per cent. oleic acid.

Although absolutely accurate results are not obtained with Burstyn's instrument since all the oleic acid is not extracted by the alcohol, portions being retained by the oil, and, on the other hand, a portion of the oil passes into solution, it is nevertheless of practical value on account of its simple manipulation.

It may be remarked that the olive oils occurring in commerce show from 0.4 to 12 and more degrees of acidity, the first being salad oils and the latter oils for technical purposes.

According to experience, oils with from 4 to 6 degrees of acidity may very well be used as machine oils. Oils showing a higher degree of acidity may be used for rough bearings, but only when iron runs upon iron, and neither zinc, copper, lead, antimony nor alloys of these metals form constituent parts of the bearing. For finer machinery the oil should not show more than one, or at the utmost two, degrees of acidity.

Bechi's test. This test is considered as very specific for discovering the presence of cotton seed oil, when mixed with olive oil. It is carried out as follows:

Prepare two solutions, viz.:

No. 1.	Nitrate of silver in crystals	1 gramme.
	Ethylic alcohol of 98 degrees	200 cubic centimeters.
	Ethylic ether	40 " "
	Nitric acid (HNO_3)	0.1 gramme.
No. 2.	Amylic alcohol	100 cubic centimeters.
	Colza oil	15 " "

10 c.c. of the silver solution No. 1, and 10 c.c. of the solution No. 2 are placed in a test tube and well agitated. Half of this mixture is poured into another test tube, and kept as a standard for comparison. The first tube is then heated in a boiling water bath, for a quarter of an hour, and then the color indications are observed. Pure olive oil should not take a brown color, but cotton-seed oil and mixtures of it with olive oil rapidly change to a red-brown, more or less dark.

Attention must be called to some precautions to be taken in order that the results may not be uncertain. The alcohol and ether employed in making solution No. 1 must be chemically pure; the colza oil which enters into solution No. 2 must be previously filtered two or three times through paper, in a water-stove at boiling point.

10 c.c. of solution No. 2 heated for a quarter of an hour in a water-stove at boiling point, together with 1 c.c. of solution No. 1, should retain their natural color.

The olive oil to be examined should be filtered through paper once, and in some cases even twice, in a water-stove at boiling point; because at times even perfectly pure olive oils will take a light-brownish tint under the test when not properly filtered; but this does not occur when they have been filtered in a hot water-stove. On the contrary cotton-seed oil and mixtures of it with olive oil retain the property of turning brown under the test even after the hot filtration.

Above all it is necessary to bear in mind that cotton-seed oil and mixtures of it with olive oil will rapidly assume a brown color when heated in contact with this reagent, viz., after a few moment's interval; while pure olive oils, which also occasionally turn slightly brown under this test before filtration, only do this after being heated for about a quarter of an hour in a hot water-stove as described.

Brullé's tests. Mr. Brullé, the director of the Agricultural Station at Nice, has perfected two methods of proving the purity of olive oils as well as the quantity and kind of oil used in adulteration.

I. In a porcelain capsule 10 cubic centimeters of oil are treated together with 0.5 cc. of fuming nitric acid; it is shaken while heat is applied till a froth appears, then 5 cc. are added of an alcoholic solution of nitrate of silver (25 per thousand in alcohol of 90°) and the application of heat is continued until the nitrate is decomposed and deposits metallic silver; this occurs at about 115° C. (239° F.). Continuing the application of heat, the metallic hues which appear on the walls of the capsule, when it is inclined and the oil flows to the opposite side, and the tints upon the surface of the liquid, are observed. The color indications which, according to Brullé, are produced by different oils are as follows:

Name of oil.	Surface of the oil.	Walls of Capsule.
Oil of Olives.	Olive green.	Green.
" " Cotton seed.	Green.	Ash color.
" " Sesamé.	Chrome green.	Blue.
" " Peanut.	Greenish yellow.	Emerald green.
" " Poppy seed.	Olive green.	Greenish blue.
" " Camelina.	Persian lake.	Light blue.
" " Linseed.	Dragon's blood.	Emerald green.
" " Rapeseed.	Persian lake.	Cyprus green.

If the oils are saponified and then treated in the foregoing manner, different color indications to the above are obtained for the various kinds of oil.

For this purpose 20 grammes of an alcoholic preparation of caustic potash is dissolved in a larger quantity of 90 per cent. alcohol, not, however, exceeding 100 cubic centimeters. Add 20 cubic centimeters of this solution in a test-tube to 10 cubic centimeters of the oil to be tested, shake thoroughly, and heat in a water-bath to 197° F., leaving it in the water 20 minutes. Empty the contents of the tube into a porcelain capsule holding say half liter; fill it with boiling water, adding 50 cubic centimeters of a 20 per cent. solution of sulphuric acid.

After shaking decant the acidulated water, again add boiling water until, after several decantations, the last traces of sulphuric acid have gone.

Treat the oil thus obtained by the first operation to get a different set of colors as per the following table:

Name of oil.	Colors (saponified).	
	Surface of the oil.	Walls of capsule.
Olive.	Cyprus green.	Orange of Mars.
Cotton.	Cobalt violet.	Sienna.
Sesamé.	Cobalt violet.	Golden yellow.
Peanut.	Light violet.	Persian lake.
Poppy seed.	Blue.	Golden ochre.
Camelina.	Blue.	Dark chrome.
Linseed.	Green.	Black.
Rape seed.	Ultramarine blue.	Burnt carmine.

In these tables the names of colors are those of water colors which are the same everywhere.

II. In an assay-tube are mixed 10 cubic centimeters of oil with 5 cubic centimeters of a solution of 25 per thousand of nitrate of silver in alcohol of 90°, and it is heated (standing in a glass vessel) in a water-bath for half an hour. The color indications which occur are observed.

Olive oil more or less rapidly changes to a fine green, which is of a lighter shade in the case of the finer qualities. Cotton seed oil turns black.

Peanut oil becomes first red brown, then green, and loses its clearness. Sesamé oil becomes a deep red. Colza oil, first black, then a dirty green. Linseed oil turns reddish. Poppy seed oil of a black-green.

Olive oil is extensively used, not only as a salad oil, for lubricating purposes and in the manufacture of soap, but also as a lamp-oil, it having the advantage of burning well and without soot, but also the disadvantage of being consumed more rapidly than any other oil. It is further employed in pharmacy, in the preparation of perfumes, and as an oil for freeing wool from fat. Its use as a Turkey red oil has already been mentioned.

Of the salad oils, the finest qualities come from Southern France, while South Italy furnishes the greater quantity of inferior table oils. Olive oils for technical purposes (fabricated oils) are produced in Calabria and Puglia, Italy, on a large scale in Greece and the Levant, and recently, also, in Northern Africa and in Spain.

The principal trading places for salad oil are Livorno and Bari, Italy, and, to a limited extent, Nice. The Italian fabricated oils are mostly shipped from Lecce in Calabria, the Levantine oils from Smyrna, and the Spanish oils from Barcelona and Malaga.

France produces annually about 250,000 hectoliters* of olive oil, imports about 22,000 tons, and exports about 2,500 tons.

2. *Oleo ferruginea*, Royle= *Oleo cuspidata*, Wall., a medium-sized, thornless tree of Asia, the black drupes of which are extracted in Afghanistan, Belloochistan, on the Himalaya, and in Punjab. The oil possesses the properties of ordinary olive oil.

(*Cupuliferæ Ametaceae.*)

1. *Beech-nut* oil (*oleum fagi sylvaticae; Bucheckeröl*, G.; *huile de faines or huile de fruits du hêtre*, F.) is extracted by cold or hot pressure from the fruits of *Fagus sylvatica*, Linn. The preparation of the oil pays only in the neighborhood of large beech forests, for instance, in Thuringia, Hanover, on the Rhine, and in Northern France.

The press-cake is used for fattening fowl and hogs; upon ruminating animals they are said to have a narcotic effect.

	Shelled beech nuts.	Beech nut cake.
Oil	21.26 p. c.	7.50 p. c.
Organic substance	64.12 "	74.74 "
Albuminous substances therein	24.00 p. c.	36.15 p. c.
Ash	4.12 "	5.63 "
Moisture	10.50 "	12.13 "
	100.00 p. c.	100.00 p. c.

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* One hectoliter = 22.0096 gallons.

Beech-nut oil is a clear oil of a pale yellow color, and, when fresh and cold drawn, has a mild taste; but that obtained by hot pressure has a somewhat acrid taste, which, however, diminishes by age, or direct shaking with cold water. It is one of the few oils which keep well. It has a specific gravity of 0.9225 at 59° F., and at this temperature is 17.5 times more thickly-fluid than water. As it chiefly consists of olein, with very little stearin and palmitin, it only solidifies at from 2° to 0.5° F. The nuts yield on an average 16 per cent. of oil.

As the annual production of oil is limited, adulterations of it are by no means uncommon. According to Henry Mayet, it is particularly distinguished by the color reactions produced by adding 10 parts of a mixture of equal parts of sulphuric and nitric acids to 10 parts of the oil. At the point of contact of the two liquids a currant-red color appears in the case of beech-nut oil; the color is orange with oil of poppies, lemon yellow with oil of sesamé or of peanuts, and no coloration is produced with olive oil. On shaking the mixture it does not change with beech-nut oil, but with oil of poppies it becomes orange-yellow, and brown with oil of sesamé or peanuts. On gradually adding 1 part of sulphuric acid and 1 part of hydrochloric acid to 5 parts of the oil, an olive-green color is produced with beech-nut or olive oil, a chestnut-brown color with oil of peanuts, and a dirty gray color with oil of poppies or of sesamé.

Nitric acid colors the oil only yellowish, *fuming nitric acid* yellow-red; the oil, as with the claïdin test, separating claïdin only in twenty-four hours.

Sulphuric acid colors the oil yellowish, then red to dark-red; the latter color is, however, not durable.

Zinc chloride calls forth a characteristic flesh color, the oil thickening at the same time.

Saponification number of the oil	196.25
Iodine number of the oil	109.00
Iodine number of the fatty acids	94.6

Beech-nut oil is used for edible and culinary purposes, and also as lamp oil. It saponifies readily, yielding a quite soft soap, which on exposure to the air becomes yellowish and finally greenish.

2. *Hazel-nut oil* (*oleum avellanæ nucum* or *oleum coryli avellanæ ; Haselnussöl*, G.; *huile de noisettes* or *huile d'avellines*, F.) from the nuts of *Corylus avellana*, Linn., the hazel-nut. The nuts contain 50 to 60 per cent. of oil:

Oil	58.82 per cent.	
Organic substances	27.63 "	
nitrogen therein		3.20 per cent.
Ash	3.10 "	
Water	10.45 "	
	100.00 "	

The nuts are pressed cold and warm, the oil obtained by cold pressure resembling in its general properties almond oil.

The oil extracted with ether differs from the expressed oil in color and consistency. It is greenish-yellow, limpid, and of an agreeable aromatic odor and taste. The yield amounts to about 63.5 per cent. and the specific gravity at 59° F. is 0.9146. Iodine number of the extracted oil 88.5; saponification number 193.4; acid number 3.2.

Expressed hazel-nut oil is a pale yellow, clear, inodorous, of a mild and agreeable taste and has a specific gravity of 0.928. It is quite thickly-fluid, being at 59° F. 18.4 times more thickly-fluid than water and at 45.5° F. 24.2 times more so. It solidifies at 1.4° to 0.4° F., and contains besides olein the glycerides of stearic and palmitic acid, and very little arachidic acid. Like almond oil it very soon becomes rancid.

Nitric acid containing some nitrous acid, has first a bleaching effect and then colors the oil greenish. Treated with some diluted fuming acid, the mixture assumes a transitory blue-green color (which is very characteristic) and in two to three hours solidifies to a yellow mass.

Sulphuric acid produces a pale blue-green color which quickly passes into gray. A mixture of equal volumes of sulphuric and nitric acids causes a peculiar dirty pale brownish color.

Zinc chloride produces at first no change in color; later on, gray-green.

The presence of hazel-nut oil in almond oil, for the adulteration of which it is frequently used, can be readily detected by the reactions of sulphuric and nitric acids.

Cold-drawn hazel-nut oil is used as a table oil and in the manufacture of perfumery, and the oil extracted by hot expression as lamp oil, machine oil, and in the manufacture of soap.

3. *Corylus colurna*, Linn., occurs in Turkey, Asia Minor, and the Himalayas. The nuts yield an oil closely resembling the above.

Gramineæ (*Glumaceæ*).

1. *Maize oil* (*oleum zeæ mais*—*Maisöl*, G., *huile de mais*, F.) from *Zea mais*, Linn., the maize or Indian corn. Of all varieties of grain maize is richest in oil, containing 6 to 8 per cent.

Oil	6.25 p. c.		7.60 p. c.	
Organic substances	82.93 "		80.76 "	
starch therein		61.95 p. c.		62.23 p. c.
albuminous substances therein		10.71 "		9.62 "
Ash	1.32 "		1.04 "	
Water	9.50 "		10.60 "	
	100.00 "		100.00 "	

The oil is not obtained by direct expression, but as a by-product in breweries and distilleries. Nearly all the fat is contained in the germs of the malted article, and to make the latter more suitable for mashing it is first crushed and freed from the germs by sifting. The germs obtained in this manner are subjected to hydraulic pressure and yield 15 per cent. of pure oil, the residue furnishing an excellent fodder.

Maize germ oil-cake.

Oil	4.35 per cent.	
Organic substances	78.85 "	
albuminous substances therein		18.54 per cent.
Ash	6.25 "	
Water	10.55 "	
	100.00 per cent.	

In case the maize malt is mashed in without freeing it from the germs, the oil is obtained in the following manner: The day before the mash is to be distilled the oil is skimmed from the surface and poured through a fine sieve into a large vat. When the vat is half full of oil it is filled up with hot water and the mixture, after thorough stirring, is filtered through linen into another vat provided with two cocks, one near the bottom for drawing off the water and the other about five inches higher up for the oil. After the filtrate has stood for a few hours, and the water has separated from the oil, the latter is carefully drawn off. If it is to be quite clear and transparent, it is poured into a glass balloon and exposed to the rays of the sun, when, after the slimy precipitate has settled, the clear oil is poured off.

By extracting the entire seed with ether only 11 per cent. of oil was obtained, while the very carefully cleansed germs yielded 22 per cent.

Maize oil is pale to golden-yellow, clear, and has a peculiarly agreeable taste and odor. It is quite thickly-fluid and has a specific gravity of 0.9215 at 59° F. It consists of olein, stearin, and palmitin, and contains some volatile oil. It solidifies to a quite solid white mass at 14° F. The oil contains 0.88 per cent. free fatty acids; the total content of fatty acids amounts to 96.67 per cent.; it also contains 1.3 per cent. of non-saponifiable, mucilaginous, and albuminous substances.

The content of olein ranges between that of olive oil and cotton-seed oil. In taste it resembles fresh ground flour. Spread in a very thin layer upon paper and exposed to the air, a membranous film is not formed inside of three weeks.

Nitric acid colors maize oil somewhat red-yellow, *fuming nitric acid* dark brown after some time, the oil solidifying in twenty-four to twenty-five hours to a yellow mass of little solidity.

Sulphuric acid produces a very characteristic dark green color, which lasts a few minutes.

A mixture of sulphuric and nitric acids effects only a red-yellow color.

Zinc chloride causes first a dark yellow color, which, after standing, changes into yellow-green.

Potash or *soda lye* rapidly yields a white soap with the oil.

Ammonia produces a cream-like emulsion.

Saponification number of the oil	181.1–189.2
" " " fatty acids	198
Iodine number of the oil	119.4–119.9
" " " fatty acids	125

Maize oil is well adapted for illuminating purposes, giving a bright white flame and developing in burning a quite high degree of heat. It is also advantageously used for dressing wool, as a machine oil, and in the manufacture of soap.

2. *Millet oil* (*Hirseöl*, G.) from the grains of *Panicum miliaceum*, Linn., a species of grain, which is cultivated partially on account of its grain and partially on account of its stalk for feeding. For use as food the grain is decorticated in special mills and "polished." The waste—the so-called polishing meal—contains 18 to 25 per cent. of oil, which is best obtained by extraction with ether. The oil is pale yellow, has a somewhat agreeable odor, and when taken internally causes, after a short time, scratching in the throat.

Like castor oil, the oil is soluble in alcohol and contains 95 per cent. of a fatty acid isomeric with ricinstearolic acid. At the ordinary temperature this acid forms a non-solidifying oil of a pale yellow color and slight odor. By long exposure to the air and light it becomes colorless and forms a thick viscous mass of rancid odor. It dissolves readily in alcohol, ether, chloroform, petroleum-ether and benzol, and with alkalies yields soap-like combinations of great softness. Aqueous solutions of the latter foam when shaken and yield flaky precipitates with lime and magnesia salts.

With *nitrous acid* (elaïdin test) millet oil does not give a solid product.

On standing a crystalline body—*panicol*—separates from the oil; the chemical composition of this body has not yet been sufficiently well established. It melts at 545° F. and when oxydized with chemical agents yields an acid close to gallic acid.

Cyperaceæ (*Glumaceæ*).

Cyperus oil (*oleum cyperi esculenti—Erdmandelöl*, G., *huile de souchet comestible*, F.) from the tubers of *Cyperus esculentus*, Linn., indigenous to Southern Europe, especially to Sicily, and cultivated in Italy and North Africa. The tubers contain as much as 20 per cent. of oil. It has a golden-yellow color, a pleasant nutty odor and taste, and is used in Egypt and Italy as a fine table oil. It has a specific gravity of 0.924; it separates stearin at below 37.5° F. It is also employed in the manufacture of soap.

According to C. Hell and S. Twer Domedoff, the oil consists essentially of the glycerides of oleic acid admixed with a small quantity of the glyceride of myristic acid.

Pteridophyta (*Lycopodiaceæ*).

Lycopodium clavatum, Linn., the club moss, is a low, creeping perennial which is found in dry woods distributed over the greater portion of the globe, but is most frequent in northern countries. The sporules form a fine, very mobile pale-yellowish powder which is free from odor and taste and is brought into commerce under the name of *lycopodium*. If this powder be triturated with glass-splinters until under the microscope it appears entirely broken up, an oil may be extracted from it by means of ether. The sporules contain up to 48.5 per cent. of oil, which is pale yellow, odorless and of a mild taste. Specific gravity = 0.925. It does not solidify even when cooled to —7.6° F. The oil contains a peculiar acid besides oleic and palmitic acids; 0.3 per cent. physostearin $C_{26}H_{44}O$ has also been established.

B. OILS OF THE ANIMAL KINGDOM.

Ruminantia Cavicornia.

1. *Neat's-foot oil* (*oleum pedum tauri; Ochsenklauenöl*, G.; *huile de pieds de bœuf*, F.) The feet of ruminants, especially of the bovine genus, contain an oil which remains fluid below the freezing point, being therefore rich in olein.

The feet collected from the slaughter-houses are soaked in cold water to free them from adhering blood, and after removing the sinews are placed perpendicularly in sufficient boiling water to cover the hoofs. In about a quarter of an hour they are to be taken out and the hoofs separated by a suitable machine. The next step is to joint them with a knife, to sever the toes from the large bone. The latter is boiled with water by steam, while the former, which are more obstinate in yielding their fat, are boiled in an open pan with water previously used for the large bones. After the boiling the liquid is left to repose, so that the oil may rise to the surface and be drawn off. The collected oil deposits after some time a thick stratum of dirty semi-fluid fat, from which the clear supernatant portion must be decanted.

The best oil, especially suitable as a lubricant for fine machines, clocks, etc., is extracted by placing the thoroughly cleansed feet in the sun or in a covered vessel near the fire. The oil thus obtained is clarified by standing and then put into small bottles.

An excellent lubricant for clocks, watches, etc., may also be prepared from the ordinary commercial neat's foot oil. Dissolve the oil in twice its volume of benzine, and set the solution in a cold room (about 37° F.) The next day pour off the clear fluid from the sediment, distil the benzine off in a *water* *bath*, repeatedly agitate the oil which remains behind with 5 per cent. of finely pulverized bicarbonate of soda, bring the mixture into small bottles well closed, and let it stand quietly to settle. In a few weeks the clear oil may be used as a lubricant for the above mentioned purposes.

Neat's-foot oil has a pure straw color, sometimes with a slight greenish shade, and when fresh a peculiar mild taste and odor. Its specific gravity is 0.915 to 0.916 at 59° F., and it solidifies at 32° to 29° F. The oil keeps very long without becoming rancid.

Neat's-foot oil consists of glycerides of oleic acid, besides very little stearic acid.

Nitric acid colors the oil only yellowish; fuming nitric acids somewhat brown-yellow, and solidifies it in twelve hours.

Sulphuric acid and a mixture of sulphuric and nitric acids color the oil brown.

Alcoholic solution of nitrate of silver shaken with the oil effects reduction.

Neat's-foot oil is subject to many adulterations, which, however, are readily detected by taste and odor, or by the nitric or sulphuric acid test.

Sophistication with fish oil is readily recognized as indicated above, or by the introduction of chlorine, which bleaches the neat's-foot oil, while the fish oil remains black or brown.

The oil is mostly produced in large slaughter houses, Buenos Ayres furnishing considerable quantities.

2. *Sheep's trotter oil* (*oleum ovis pedum; Schafpfotenöl* G.; *huile de pieds de mouton*, F.) The trotters of *ovis aries*, Linn., the sheep, also contain an oil rich in olein. It is obtained in the same manner as neat's-foot oil. It resembles the latter, only its taste and odor are still more characteristic. It has a specific gravity of 0.9175, and solidifies at 32° to 29° F.

Sulphuric acid does not produce, as in neat's-foot oil, a brown color, but at first a dark red-yellow one.

Solidungula.

Horse-foot oil (*oleum pedum equorum; Pferdefussöl*, G.; *huile de pieds de cheval*, F.). The feet of horses yield an oil very similar to neat's-foot oil, with a specific gravity of 0.913 at 59° F. It being very difficult to detect with sulphuric acid, which gives a brown-yellow color, it is frequently used for adulterating neat's-foot oil. The specific gravity furnishes, however, some guide.

Gallinæ.

Egg oil (*oleum ovorum; Eieröl*, G.; *huile d'oeufs*, F.) is obtained from the yolks of fowls' or hens' eggs. By boiling the yolks are changed into a readily friable mass, from which the oil is obtained either by pressure or by extraction with ether.

The oil obtained by pressure is reddish-yellow, thickly fluid, inodorous, of a mild taste, and neutral. By long standing palmitin is separated. The oil solidifies to a granular mass at 39° F.

The oil extracted with ether has a beautiful yellow color, a somewhat disagreeable flavor, and contains a viscous substance, which is separated by filtering.

The oil extracted with ether from ducks' eggs is of a darker golden yellow than that from hens' eggs, and lacks the peculiar odor of the latter.

The oil extracted with benzine from ostriches' eggs, the yolk of which contains up to 25.12 per cent., oxidizes very rapidly on exposure to the air. Specific gravity = 0.915.

Egg oil consists chiefly of olein and palmitin, and contains besides $\frac{1}{800}$ per cent. of cholesterin. It is readily soluble in ether and in 22.5 parts of 90 per cent. spirit of wine. It is subject to many adulterations, which, however, can readily be detected by the methods already described. Coloration with turmeric can be detected by saponification, pure egg oil yielding a yellowish soap, and the colored article a brown soap.

Egg oil is obtained on a large scale by extraction with pure petroleum ether as a by-product in the manufacture of egg albumen. It is much used in tawing as a substitute for olive oil, and for pharmaceutical purposes.

Hens' eggs contain on an average 11.50 per cent. of oil.

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